

APPENDIX

Investigation , Cure of Vibration
Difficulties with Optical Equipment

Final Report, Part I

Job 646

23 August 1971

APPENDIX

Final Report, Part I

Investigation, Cure of Vibration Difficulties
with Optical Equipment

23 August 1971



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Job 646



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Section 1.0

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1.1 Copy of Work Statement from DBR 667-4

5.6 Work Statement

5.6.1 Phase I

1. Review customer equipment for vibration limitations.
2. Review potential problem areas in the equipment.
3. Select five types of instruments for test. Attempt to perform preliminary tests to insure a problem does exist with each instrument chosen and, if not, reselect. Generate a Project Plan for further investigation on the selected types.
4. Perform vibration analyses including dynamic and relative motion tests on the five selected types as appropriate.
5. Report on the extent of the vibration problems and establish the disturbing levels.
6. Prepare and submit cost estimates and detailed plans for Phase 2.

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with Optical Equipment

- 1.1 An initial meeting was held on 20 April 1971 through 23 April 1971, resulting in choices of equipment for investigation, and a meeting with [] resulting in an understanding of the STAT ambient vibration data to be made available.
- 1.2 From 26 April through 15 May 1971 the contractor devised equipment to be used in the vibration difficulty investigation.
- 1.3 The investigation at the site was initiated on 17 May 1971. The first three days were largely concerned with setting up and checking instruments and familiarization with the equipment.
- 1.4 An investigation of a 10X, 20X, 40X Enlarger was made during 19, 20, and 21 May 1971.

1.2.1 Copy of First Interim Report (Contd.)

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2.0 Investigation of 10X, 20X, 40X Enlarger, S/N-3.2.1 Ambient Floor Vibration Input

The floor vibration level was amazingly high in the room at Enlarger S/N-3. A spectrum analysis (manual sweep) was made in order to understand the reason for the unusually high disturbance.

Dominant peaks were found as follows (probable sources are noted):

| <u>Peak to Peak Excursion Microinches</u> | <u>Frequency</u> | <u>Probable Source</u> |
|---|------------------|--|
| No estimate | 4 to 7 cps | Basic Enlarger resonance reflected in floor. |
| 8 to 10 | 12 cps | Not identified. |
| 13 | 28 to 30 cps | 1725 to 1800 RPM Electric Motors. |
| 3. | 55 to 65 cps | 60 cycle "hum" from motor and brake field coils. |
| 3. | 115 to 120 cps | Transformer "hum" from many small units or one large unit. <u>Probably from fluorescent light ballasts.</u> |

The normal levels are 1/2 to 1/4 these levels.

2.2 Response of Enlarger to Floor Ambient

A similar manual spectrum analysis was made on the base of the machine which is isolated. At the lower frequencies (up to 30 cps) we found some magnification of levels. Obviously the vibration isolation is not effective at low frequencies as expected.

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2.3 Self-Induced Vibration

Considerable 60 cps and 120 cps disturbance was discovered throughout the unit from base to lens mount and easel. This was traced to field coils of the electric motors and brakes, as with power "off" the level dropped to less than one fourth. These are motors for the film drive and brakes which lock the platen position.

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3.0 Program Next Period

· Use predicted ambient data and drive floors at these levels
at the instruments to determine response and optical effect.



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Second Interim Report
Cure of Vibration Difficulties
on Optical Equipment

Period of Report: 24 May through 4 June 1971

1.0 General

The investigation, at the site, of the five chosen instruments was completed during this period. After data reduction and analysis it may prove necessary to conduct some additional measurements. This will be determined during the analytical effort in the next period.

Following is a brief log of the vibration measurement effort during this period:

1.1 Mann Comparator (Type 1210) S/N 104

From 24 May through 25 May 1971 vibration measurements were made on the 1210 Comparator.

1.2 Mann Scanning Microdensitometer (Type 1032 T) S/N 07

From 26 May through first half of 28 May 1971 vibration measurements were made on the Microdensitometer.

1.3 Beacon Enlarger, S/N 001

From last half of 28 May through first half of 2 June 1971 vibration measurements were conducted.

1.4 Dual Viewing Microstereoscope, Mod. II, S/N 4

Vibration measurements were conducted from last half of 2 June through 3 June 1971.

1.5 [redacted] Meeting and Report

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[redacted] attended the meeting with
[redacted] on the afternoon of 27 May 1971.

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1.6 High Precision Stereocomparator - Quick Check

A quick check of the ambient vibration on the seismic block, the isolated granite base, and the instrument stage was made on the afternoon of 24 May 1971.

1.7 Proposal to Add High Precision Stereocomparator to Contract

As requested, a proposal was submitted on 27 May 1971 to cover an investigation of this unit, which can be initiated after 15 July 1971 if desired.

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2.0 Summary of Investigation

A brief summary of the investigation follows:

2.1 Mann 1210 Comparator - Investigation

The ambient floor vibration was relatively quiet in this room. The card punch and teletype added about 50% to the ambient level. Door closing impulses resulted in vibration amplitudes about 8X higher than ambient.

Vibration levels at various points on the unit along X, Y, and Z directions were measured and spectral analyses were manually made in 5 Hz steps up to 100 Hz and 10 Hz steps to 200 Hz.

The floor pads under the unit resulted in magnification of 2X to 3X below 40 Hz and attenuated input at higher frequencies except for 120 Hz where they magnified 2X (this could be caused by the on-board fluorescent ballasts).

A significant resonance of the eye piece in a transverse direction was observed with a 9X magnification of the motion at 44 Hz.

The unit appeared to be relatively quiet and the significance to performance must await the reduction of the extensive data taken.

2.2 Microdensitometer - 1032 T, S/N 07

The ambient floor vibration in the clean room was relatively high, caused primarily by the clean room air circulating fans. Initially with fans "ON" the vibration level at the floor was 3X to 4X higher than with fans "OFF". Part way through the investigation new fan belts were installed. As seen at the platen of the unit the vibration level with fans "ON" dropped to 1/10 the former value before belt change. This illustrates the sensitivity of vibration disturbance on-board instruments to the condition of adjacent rotary machinery.

The response of various parts of the unit in X, Y, and Z directions was measured and manual spectral analyses made. The most significant resonance discovered was transverse (X) at the platen at 30 Hz.

The vibration isolation pad and the isolators between the base and the machine were measured for natural frequency and damping. Both are quite non-linear and transmit and magnify some of the disturbing frequencies.

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2.2 Microdensitometer - 1032 T, S/N 07 (Contd.)

Measurements were taken so that correlation can be made between platen vibration relative to the lens and density readings.

The evaluation of the effect of vibration on the performance of the unit and recommendations for improvements to vibration isolation, if any, must await full data reduction and analysis.

2.3 Beacon Enlarger, S/N 001

The ambient floor vibration was typical for the area. There was a higher amplitude of 60 Hz disturbance than normal, presumably due to the large fan that provides vacuum for the easel.

Ambient vibrations were measured at the floor, mount pad, lens holder, and easel in the X, Y, and Z directions. Manual spectral analyses were made of these responses.

The natural frequency of the vibration isolators and damping ratios were measured.

The floor was driven at 10 Hz, at the predicted worst case amplitude

[redacted] The response at the lens mount was measured in the X, Y, and Z directions. This test was repeated driving the floor up to the resonant frequencies of the mounts which ranged from 13 to 15-1/2 Hz depending on the position of the easel.

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No significant magnifications of vibration disturbance were discovered. The vibration isolation system is adequate. cursory examination of the data indicates no limitation of performance will be experienced with this machine under predicted worst case vibrations.

2.4 Dual Viewing Microstereoscope

The ambient floor vibration in the T & EB Laboratory (fourth floor) was 1-1/2X to 2X the levels measured in the other areas. This disturbance increase is mostly due to 10 Hz and 20 Hz building vibrations apparently caused by external sources. This was about half of the predicted worst case amplitude. Ambient vibration responses of the instrument were measured at various locations both with the table normally wheel-mounted and with wheels removed. This ruled out possible degrading effects of the wheel mounting.

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2.4 Dual Viewing Microstereoscope (Contd.)

The floor was driven to predicted worst case amplitude, and higher. The instrument performance was monitored with a calibrated graticule at full 75X image magnification. Performance was measured under ambient building and operator-induced disturbances.

Two significant resonances were discovered which materially degrade performance. These were a front-to-back vibration of the platen at 18 Hz and a rocking of the microscope support structure on its three-point suspension at 25 Hz. A quick fix with gun tape on the platen made major improvement. A wedge under a corner of the microscope support made further improvement.

A better analysis will result from the data reduction.

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3.0 Program Next Period

The data acquisition activity is substantially complete except for the expected need for additional or confirmation measurements that will be determined during data reduction.

The next three to four weeks will cover the data reduction and analysis activity. An initial report will be written.

After completing the measurement of any final data during the next trip now tentatively scheduled for early July, a final report will be submitted.



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Third Interim Report
Cure of Vibration Difficulties
on Optical Equipment

Period of Report: 4 June through 2 August 1971

1.0 General

The initial measurements taken during the previous period were analyzed and the final report was started in the period through 23 July 1971. A rough draft copy was provided cognizant technical personnel pending clean up and completion of the first part of the report. In the period 26 July through 2 August 1971, responses of the five equipments to the predicted worst case ambient floor vibration were measured by driving the floor at the equipments to these worst case levels. With these response measurements the data accumulation is complete for the five instruments. Their analysis and the report on these units will be completed in the next period.

A demonstration of the vibration measurement and floor drive technique was given to interested Management personnel at the request of

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Following is a brief log of the vibration measurement effort during this period:

1.1 Equipment Set-up and Calibration

The vibration instruments were set up and calibrated on 26 July 1971. Two of the instruments were damaged in shipment. One was repaired. The Brush Recorder was not repaired and had to be replaced.

1.2 Dual Viewing Microstereoscope, Mod II, S/N 4

Response measurements to predicted worst case floor ambient vibration were made on 27 July 1971. Demonstrations of the floor drive technique and response measurements were also made on 28 July 1971.

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1.3 Mann Comparator (Type 1210), S/N 104

Response measurements to predicted floor ambients were made on 29 July 1971.

1.4 10X, 20X, 40X Enlarger, S/N-3

Response measurements to predicted floor ambients were made on 30 July 1971. Comparative 40X enlargements of resolution charts were also made with and without "worst case" driven vibration. Only marginal, if any, degradation was noted under simulated "worst case" ambient vibration. However, the unit is easily disturbed by the operator, which was demonstrated.

1.5 Mann Scanning Microdensitometer (Type 1032 T)

Response measurements to predicted floor ambients were made on 2 August 1971. Comparative density traces were recorded of an edge, with and without simulated "worst case" driven vibration of the floor. No discernible effect on the traces was noted, resulting from the floor vibration.

1.6 Response of "Air Bag" Isolation of Surface Plate

Response of the surface plate to existing ambient vibration was measured in the A. D. Lab. Floor ambient (vertical and horizontal) was recorded concurrently with the vertical and horizontal vibration of the top of the surface plate. These data will be analyzed later for spectrum and response.

2.0 Program for Next Period

Analyze the response data on the five equipments and complete the report on these items.

If authorized, do additional analysis of spectrums to establish a basis for a generalized vibration environment specification for buildings for this use. Insure the practicality of the specification by relating it to results of the typical optical devices tested to date.



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2.2 Mathematical Basis of the Power Density Spectra

The method used is based on a Fourier analysis of the autocorrelation function of the digitized data sample. The data is digitized at 1/125 second intervals on the basis that the highest frequency of interest is 60 Hz. (The Nyquist frequency is 1/2 the sample frequency or 62-1/2 Hz, in other words the data is valid to 1/2 the sample frequency). It was decided that a 2 second duration sample (250 points) adequately characterized each vibration record. A typical set of data is given on Figure 2.2.1. The data set was first normalized to zero mean and unit variance.

The autocorrelation function was then calculated as follows: (fifty steps were used):

Let X_j represent a member of the original set and Y_j represent a corresponding member of the shifted set.

Then:

$$R_g = \frac{(n-g) \sum_{j=0}^{n-g} X_j Y_j - \left[\sum_{j=0}^{n-g} X_j \right] \left[\sum_{j=0}^{n-g} Y_j \right]}{\sqrt{\left[(n-g) \sum_{j=0}^{n-g} X_j^2 - \left(\sum_{j=0}^{n-g} X_j \right)^2 \right] \left[(n-g) \sum_{j=0}^{n-g} Y_j^2 - \left(\sum_{j=0}^{n-g} Y_j \right)^2 \right]}}$$

The Harmonic analysis of the autocorrelation function was calculated as follows:

$$P(f) = \frac{2}{f_{ST}} \sum_{j=0}^Q R_j \cos\left(j \frac{\pi}{Q}\right)$$

The truncation of the data (due to the short sample) was accommodated by taking the first and last steps at 1/2 value. A smoothing function was applied to the data to avoid statistical noise from the finite data intervals (1-1/4 Hz steps for the Fourier analysis). This smoothing function had the form of the "Witch of Agnesi" with a half height width of 2.4 Hz. The data was calculated for 1-1/4 Hz intervals in terms of the square of the original units (velocity). Figure 2.2.2 is a typical readout from the computer run.

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Figure 2.2.1 Sample Data Set for Power Density Spectrum - Test 54a-1

| | | | | | |
|----|-------|----|-------|----|-------|
| 0 | 28.50 | 30 | 20.75 | 60 | 20.75 |
| 1 | 21.00 | 31 | 23.00 | 61 | 23.00 |
| 2 | 18.25 | 32 | 29.00 | 62 | 27.25 |
| 3 | 19.25 | 33 | 28.50 | 63 | 25.25 |
| 4 | 25.00 | 34 | 25.50 | 64 | 27.00 |
| 5 | 31.75 | 35 | 26.25 | 65 | 24.50 |
| 6 | 33.00 | 36 | 24.75 | 66 | 25.00 |
| 7 | 29.00 | 37 | 28.00 | 67 | 26.00 |
| 8 | 24.50 | 38 | 28.50 | 68 | 27.00 |
| 9 | 23.00 | 39 | 27.75 | 69 | 25.00 |
| 10 | 26.00 | 40 | 23.50 | 70 | 26.00 |
| 11 | 29.75 | 41 | 23.00 | 71 | 29.00 |
| 12 | 27.50 | 42 | 23.50 | 72 | 26.00 |
| 13 | 24.00 | 43 | 24.00 | 73 | 23.00 |
| 14 | 19.00 | 44 | 30.00 | 74 | 23.00 |
| 15 | 20.75 | 45 | 25.00 | 75 | 24.00 |
| 16 | 25.00 | 46 | 23.00 | 76 | 24.50 |
| 17 | 29.00 | 47 | 21.50 | 77 | 26.00 |
| 18 | 28.50 | 48 | 23.25 | 78 | 28.50 |
| 19 | 27.75 | 49 | 25.50 | 79 | 26.00 |
| 20 | 22.00 | 50 | 30.00 | 80 | 22.25 |
| 21 | 24.75 | 51 | 30.00 | 81 | 21.75 |
| 22 | 23.75 | 52 | 26.00 | 82 | 25.00 |
| 23 | 23.50 | 53 | 23.00 | 83 | 30.00 |
| 24 | 26.25 | 54 | 20.50 | 84 | 30.25 |
| 25 | 28.50 | 55 | 26.50 | 85 | 31.00 |
| 26 | 29.25 | 56 | 28.25 | 86 | 25.00 |
| 27 | 27.00 | 57 | 31.50 | 87 | 22.00 |
| 28 | 27.00 | 58 | 28.00 | 88 | 21.75 |
| 29 | 23.00 | 59 | 25.00 | 89 | 23.00 |

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Figure 2.2.1 (Contd.) Sample Data Set for Power Density Spectrum - Test 54a-1

| | | | | | |
|-----|-------|-----|-------|-----|-------|
| 90 | 27.75 | 120 | 17.25 | 150 | 24.00 |
| 91 | 29.25 | 121 | 21.00 | 151 | 20.25 |
| 92 | 29.00 | 122 | 28.00 | 152 | 30.00 |
| 93 | 21.00 | 123 | 30.25 | 153 | 30.00 |
| 94 | 19.00 | 124 | 27.00 | 154 | 26.00 |
| 95 | 21.00 | 125 | 24.75 | 155 | 23.25 |
| 96 | 29.00 | 126 | 23.25 | 156 | 24.25 |
| 97 | 29.50 | 127 | 21.25 | 157 | 24.25 |
| 98 | 27.00 | 128 | 20.75 | 158 | 25.00 |
| 99 | 24.00 | 129 | 21.00 | 159 | 20.25 |
| 100 | 23.00 | 130 | 27.25 | 160 | 24.00 |
| 101 | 29.00 | 131 | 30.00 | 161 | 25.50 |
| 102 | 31.00 | 132 | 31.00 | 162 | 32.00 |
| 103 | 32.00 | 133 | 32.50 | 163 | 30.00 |
| 104 | 26.00 | 134 | 29.00 | 164 | 28.75 |
| 105 | 20.50 | 135 | 27.00 | 165 | 21.00 |
| 106 | 16.50 | 136 | 19.00 | 166 | 20.25 |
| 107 | 20.00 | 137 | 17.50 | 167 | 23.00 |
| 108 | 25.00 | 138 | 20.25 | 168 | 28.00 |
| 109 | 32.00 | 139 | 25.25 | 169 | 31.00 |
| 110 | 34.75 | 140 | 27.00 | 170 | 26.00 |
| 111 | 27.00 | 141 | 25.50 | 171 | 23.00 |
| 112 | 24.00 | 142 | 27.00 | 172 | 19.00 |
| 113 | 19.00 | 143 | 30.25 | 173 | 22.75 |
| 114 | 20.00 | 144 | 31.75 | 174 | 25.50 |
| 115 | 25.00 | 145 | 26.00 | 175 | 29.00 |
| 116 | 31.50 | 146 | 23.50 | 176 | 31.25 |
| 117 | 34.00 | 147 | 21.25 | 177 | 27.00 |
| 118 | 29.50 | 148 | 22.75 | 178 | 22.25 |
| 119 | 25.00 | 149 | 21.50 | 179 | 21.25 |

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Figure 2.2.1 (Contd.) Sample Data Set for Power Density Spectrum, Test 54a-1

| | | | | | |
|-----|-------|-----|-------|-----|-------|
| 180 | 24.00 | 210 | 27.75 | 240 | 27.00 |
| 181 | 27.00 | 211 | 23.00 | 241 | 28.50 |
| 182 | 26.75 | 212 | 23.00 | 242 | 29.00 |
| 183 | 27.25 | 213 | 24.00 | 243 | 22.75 |
| 184 | 24.00 | 214 | 25.00 | 244 | 22.75 |
| 185 | 23.25 | 215 | 25.00 | 245 | 18.50 |
| 186 | 25.00 | 216 | 24.25 | 246 | 23.00 |
| 187 | 30.00 | 217 | 25.25 | 247 | 26.00 |
| 188 | 29.50 | 218 | 25.25 | 248 | 32.25 |
| 189 | 25.00 | 219 | 27.75 | 249 | 29.50 |
| 190 | 20.50 | 220 | 26.75 | 250 | 25.75 |
| 191 | 21.00 | 221 | 30.50 | | |
| 192 | 23.50 | 222 | 25.00 | | |
| 193 | 28.00 | 223 | 22.00 | | |
| 194 | 30.75 | 224 | 19.00 | | |
| 195 | 29.25 | 225 | 21.00 | | |
| 196 | 28.50 | 226 | 27.00 | | |
| 197 | 25.00 | 227 | 31.00 | | |
| 198 | 22.00 | 228 | 34.25 | | |
| 199 | 22.00 | 229 | 30.00 | | |
| 200 | 24.50 | 230 | 22.00 | | |
| 201 | 25.00 | 231 | 18.25 | | |
| 202 | 27.00 | 232 | 19.25 | | |
| 203 | 28.00 | 233 | 25.00 | | |
| 204 | 26.25 | 234 | 30.50 | | |
| 205 | 24.00 | 235 | 30.00 | | |
| 206 | 23.50 | 236 | 25.25 | | |
| 207 | 22.75 | 237 | 24.50 | | |
| 208 | 27.25 | 238 | 24.00 | | |
| 209 | 28.50 | 239 | 24.00 | | |

TEST 54-a1

TEST 54-a2

| f_{Hz} | $P_v(f)$ | $P_D(f)$ | $\sqrt{P_D(f)}$ | $P_v(f)$ | $P_D(f)$ | $\sqrt{P_D(f)}$ |
|----------|------------|------------|-----------------|------------|------------|-----------------|
| .33 | .4328 e-08 | | | .2167 e-07 | | |
| 1.25 | .5951 e-08 | .9663 e-10 | .9830 e-05 | .2689 e-07 | .4359 e-09 | .2088 e-04 |
| 2.50 | .5107 e-08 | .2070 e-10 | .4549 e-05 | .2882 e-07 | .1168 e-09 | .1081 e-04 |
| 3.75 | .7942 e-08 | .1431 e-10 | .3782 e-05 | .4177 e-07 | .7524 e-10 | .8674 e-05 |
| 5.00 | .8559 e-08 | .8672 e-11 | .2945 e-05 | .5724 e-07 | .5800 e-10 | .7616 e-05 |
| 6.25 | .1354 e-07 | .8846 e-11 | .2974 e-05 | .9759 e-07 | .6328 e-10 | .7955 e-05 |
| 7.50 | .2109 e-07 | .9497 e-11 | .3082 e-05 | .1451 e-06 | .6536 e-10 | .8085 e-05 |
| 8.75 | .2321 e-07 | .9334 e-11 | .3055 e-05 | .2220 e-06 | .7345 e-10 | .8571 e-05 |
| 10.00 | .3058 e-07 | .7770 e-11 | .2788 e-05 | .2076 e-06 | .5260 e-10 | .7252 e-05 |
| 11.25 | .6041 e-07 | .1209 e-10 | .3477 e-05 | .1904 e-06 | .3811 e-10 | .6174 e-05 |
| 12.50 | .6557 e-07 | .1079 e-10 | .3285 e-05 | .2239 e-06 | .3629 e-10 | .6024 e-05 |
| 13.75 | .7035 e-07 | .9426 e-11 | .3070 e-05 | .2678 e-06 | .3588 e-10 | .5990 e-05 |
| 15.00 | .8860 e-07 | .9974 e-11 | .3158 e-05 | .2945 e-06 | .3316 e-10 | .5758 e-05 |
| 16.25 | .9520 e-07 | .9132 e-11 | .3022 e-05 | .3231 e-06 | .3099 e-10 | .5567 e-05 |
| 17.50 | .1144 e-06 | .9462 e-11 | .3076 e-05 | .3584 e-06 | .2964 e-10 | .5445 e-05 |
| 18.75 | .1663 e-06 | .1202 e-10 | .3467 e-05 | .3189 e-06 | .2297 e-10 | .4793 e-05 |
| 20.00 | .1367 e-06 | .2659 e-11 | .2943 e-05 | .2444 e-06 | .1548 e-10 | .3934 e-05 |
| 21.25 | .8542 e-07 | .4848 e-11 | .2202 e-05 | .1739 e-06 | .9756 e-11 | .3123 e-05 |
| 22.50 | .5747 e-07 | .2876 e-11 | .1696 e-05 | .1405 e-06 | .7031 e-11 | .2652 e-05 |
| 23.75 | .3252 e-07 | .1463 e-11 | .1210 e-05 | .9319 e-07 | .4185 e-11 | .2046 e-05 |
| 25.00 | .2517 e-07 | .1020 e-11 | .1010 e-05 | .6600 e-07 | .2675 e-11 | .1636 e-05 |
| 26.25 | .1483 e-07 | .5475 e-12 | .7399 e-06 | .4965 e-07 | .1825 e-11 | .1351 e-05 |
| 27.50 | .1273 e-07 | .4285 e-12 | .6546 e-06 | .4350 e-07 | .1457 e-11 | .1207 e-05 |
| 28.75 | .1126 e-07 | .3634 e-12 | .6028 e-06 | .4289 e-07 | .1314 e-11 | .1147 e-05 |
| 30.00 | .1142 e-07 | .3214 e-12 | .5670 e-06 | .3718 e-07 | .1046 e-11 | .1023 e-05 |
| 31.25 | .7302 e-08 | .1894 e-12 | .4352 e-06 | .2297 e-07 | .5958 e-12 | .7719 e-06 |
| 32.50 | .6637 e-08 | .1592 e-12 | .3990 e-06 | .1752 e-07 | .4201 e-12 | .6482 e-06 |
| 33.75 | .4966 e-08 | .1104 e-12 | .3323 e-06 | .1433 e-07 | .3186 e-12 | .5645 e-06 |

Figure 2.2.2 Computer Readout, Power Density Spectrum

Test 54a-1 and 54a-2

T & EB Laboratory Floor Ambient Normal
vs. Walking Nearby

TEST 54-a1

TEST 54-a2

| f | $P_v(f)$ | $P_D(f)$ | $\sqrt{P_D(f)}$ | $P_v(f)$ | $P_D(f)$ | $\sqrt{P_D(f)}$ |
|-------|-----------------------|-------------------|-----------------|-----------------------|-------------------|-----------------|
| 35.00 | .5503 e-08 | .1138 e-12 | .3373 e-06 | .1375 e-07 | .2844 e-12 | .5333 e-06 |
| 36.25 | .4824 e-08 | .9298 e-13 | .3049 e-06 | .1243 e-07 | .2395 e-12 | .4894 e-06 |
| 37.50 | .5250 e-08 | .9456 e-13 | .3075 e-06 | .1129 e-07 | .2034 e-12 | .4510 e-06 |
| 38.75 | .4177 e-08 | .7046 e-13 | .2654 e-06 | .8819 e-08 | .1488 e-12 | .3857 e-06 |
| 40.00 | .4055 e-08 | .6420 e-13 | .2534 e-06 | .9140 e-08 | .1447 e-12 | .3804 e-06 |
| 41.25 | .2998 e-08 | .4462 e-13 | .2112 e-06 | .7859 e-08 | .1170 e-12 | .3421 e-06 |
| 42.50 | .3355 e-08 | .4705 e-13 | .2169 e-06 | .8684 e-08 | .1218 e-12 | .3490 e-06 |
| 43.75 | .2516 e-08 | .3329 e-13 | .1825 e-06 | .7448 e-08 | .9856 e-13 | .3139 e-06 |
| 45.00 | .2821 e-08 | .3529 e-13 | .1878 e-06 | .6951 e-08 | .8695 e-13 | .2949 e-06 |
| 46.25 | .2406 e-08 | .2849 e-13 | .1688 e-06 | .5628 e-08 | .6665 e-13 | .2582 e-06 |
| 47.50 | .3132 e-08 | .3516 e-13 | .1875 e-06 | .5830 e-08 | .6545 e-13 | .2558 e-06 |
| 48.75 | .2845 e-08 | .3033 e-13 | .1741 e-06 | .5652 e-08 | .6024 e-13 | .2454 e-06 |
| 50.00 | .2986 e-08 | .3025 e-13 | .1739 e-06 | .6706 e-08 | .6795 e-13 | .2607 e-06 |
| 51.25 | .2564 e-08 | .2473 e-13 | .1573 e-06 | .5831 e-08 | .5623 e-13 | .2371 e-06 |
| 52.50 | .3385 e-08 | .3111 e-13 | .1764 e-06 | .6476 e-08 | .5951 e-13 | .2440 e-06 |
| 53.75 | .5333 e-08 | .4676 e-13 | .2162 e-06 | .7685 e-08 | .6914 e-13 | .2629 e-06 |
| 55.00 | .8775 e-08 | .7348 e-13 | .2711 e-06 | .1151 e-07 | .9636 e-13 | .3104 e-06 |
| 56.25 | .6638 e-08 | .5314 e-13 | .2305 e-06 | .1037 e-07 | .8299 e-13 | .2881 e-06 |
| 57.50 | .5275 e-08 | .4041 e-13 | .2010 e-06 | .8728 e-08 | .6687 e-13 | .2586 e-06 |
| 58.75 | .4177 e-08 | .3066 e-13 | .1751 e-06 | .6795 e-08 | .4987 e-13 | .2233 e-06 |
| 60.00 | .4421 e-08 | .3111 e-13 | .1764 e-06 | .6615 e-08 | .4654 e-13 | .2157 e-06 |
| 61.25 | .2802 e-08 | .1892 e-13 | .1375 e-06 | .5526 e-08 | .3731 e-13 | .1932 e-06 |
| 62.50 | .2881 e-08 | .1868 e-13 | .1367 e-06 | .5737 e-08 | .3720 e-13 | .1929 e-06 |
| sums | .2578 e-05 | .5414 e-09 | .2327 e-04 | .7915 e-05 | .2432 e-08 | .4932 e-04 |
| | σ_v^2 | σ_D^2 | σ_D | σ_v^2 | σ_D^2 | σ_D |
| | (in/sec) ² | (in) ² | in. | (in/sec) ² | (in) ² | in. |

Figure 2.2.2 (Contd.) Computer Readout, Power Density Spectrum

Test 54a-1 and 54a-2

T & EB Laboratory Floor Ambient Normal
vs. Walking Nearby

| | | |
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2.3 Mathematical Basis to Estimate Damping in a Complex Vibration

2.3.1 Damping Ratio from Power Spectra

Estimating damping ratio from a power spectra of the response of a spring mass system to noise excitation can be done providing the dominant responses are separated in frequency and have damping below .15. The estimate depends on judging the half height width of the resonant peak. Two judgments must be made, i. e., the resonant frequency and the position of half height above the noise which is not part of the resonant response. For the power spectra in this report the following empirical expression adequately accounts for the inherent damping of the statistical process.

$$\text{Damping Ratio} = \xi = \frac{k W}{f}$$

W = the half height width of the peak on power spectra in Hz.
k = 0.39
f = resonant frequency in Hz.

2.3.2 Damping Ratio from Impulse

The damping ratio from a amplitude vs. frequency plot from the harmonic (Fourier) analysis of the response from an impulse can be estimated in the same way by finding the half height width in Hz of each dominant resonant peak providing they are sufficiently separated.

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties

| <u>Item</u> | <u>Description and Significant Parameters</u> | | | | | | | | | | |
|-------------------------------------|---|-------------------------------------|----------|-------------------------------|---------------------------|---------------------|---|------------------------|------------|---------------------------------|--------------|
| 1. | <p><u>Floor Drive Vibrator</u>, DMI Part No. 30619 - Capable of imparting vertical, sinusoidal excitation to any floor system, at frequencies from 4 to 41 Hz, with force inputs from 280 lbs. to zero lbs. The Vibrator is powered by an SCR speed controlled, variable speed universal motor, 0 - 2500 RPM, 1/2 HP. It delivers 12.6 inch-lbs. torque, from 1250 to 2500 RPM, and 7.6 inch-lbs. torque from 0 to 1250 RPM. Dayton shunt-wound DC motor Model 6K064. Power supply is 60 Hz, 115-volt AC standard line voltage.</p> | | | | | | | | | | |
| 2. | <p><u>Ling Electronics Vibrator</u>, Model 203, is a miniature drive unit for use directly on equipments.</p> <p>It is of permanent magnet design, depending for its operation on the interaction between the steady magnetic field and an oscillating current produced in a moving coil. Drive current is derived from the output of the function generator (Item 3) amplified by the DMI Drive Amplifier (Item 3a).</p> <p>Effective armature mass is 20 grams, and was increased for this application by attachment of a 291.2 gram external weight to the tapped hole provided for test specimens. The driving force is thus provided to the equipment through the vibrator base, referenced to the inertial reactions of the 311.2-gram effective mass.</p> <p><u>Leading Particulars</u></p> <table> <tr> <td>Current at mid frequency: (nominal)</td><td>2.5 amps</td></tr> <tr> <td>D. C. force factor: (nominal)</td><td>0.589kg/amp (1.3 lbs/amp)</td></tr> <tr> <td>Thrust sine factor:</td><td>6.6 lb. (Forced Air Cooling) 4.4 lb. (Natural Cooling)</td></tr> <tr> <td>Sprung mass resonance:</td><td>50 - 60 Hz</td></tr> <tr> <td>Fundamental armature resonance:</td><td>Above 10 kHz</td></tr> </table> | Current at mid frequency: (nominal) | 2.5 amps | D. C. force factor: (nominal) | 0.589kg/amp (1.3 lbs/amp) | Thrust sine factor: | 6.6 lb. (Forced Air Cooling) 4.4 lb. (Natural Cooling) | Sprung mass resonance: | 50 - 60 Hz | Fundamental armature resonance: | Above 10 kHz |
| Current at mid frequency: (nominal) | 2.5 amps | | | | | | | | | | |
| D. C. force factor: (nominal) | 0.589kg/amp (1.3 lbs/amp) | | | | | | | | | | |
| Thrust sine factor: | 6.6 lb. (Forced Air Cooling) 4.4 lb. (Natural Cooling) | | | | | | | | | | |
| Sprung mass resonance: | 50 - 60 Hz | | | | | | | | | | |
| Fundamental armature resonance: | Above 10 kHz | | | | | | | | | | |

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties (Contd.)

| <u>Item</u> | <u>Description and Significant Parameters</u> | |
|-------------|---|--|
| 2. | <u>Ling Electronics Vibrator -</u> | |
| | <u>Leading Particulars (Contd.)</u> | |
| | Maximum Bare Table Acceleration | 100 g |
| | Excursion: | 0.1 inch |
| | Operation frequency range: | 5 - 10 kHz |
| | Flexure stiffness: | 7.25 kg/amp (16.75 lbs/amp) |
| | Cooling: | Natural or Forced Air |
| | Weight with Trunnion | 8.5 lbs. |
| | <u>Armature</u> | |
| | D. C. Resistance: (cold) | 1.5 ohm |
| | Maximum working current: (nominal) | 2.5 amp (unblown) 3.5 amp (blown) |
| | Effective armature weight: | 20 grams |
| | Field: | Permanent Magnet |
| | Shaker input power: | 14 watts Natural Cooling Up to 20 watts Forced Air Cooling |

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties (Contd.)

| <u>Item</u> | <u>Description and Significant Parameters</u> |
|-------------|---|
| 3. | <p><u>Function Generator</u> - Hewlett-Packard Model 203A - A low-frequency function generator providing low distortion square and sinusoidal test signals.</p> <p>Frequency Range: .005 Hz to 60 kHz in seven decade range</p> <p>Frequency Stability: $\pm 1\%$</p> <p>Output Waveform: Sine and square waves (Available simultaneously)</p> <p>Output Impedance: 600 ohms</p> <p>Output Power: 5 volts into 600 ohms (40 mW)</p> <p>Distortion: Total Harmonic Distortion, hum and noise > 64 db below fundamental at full output</p> <p>Frequency Response: $\pm 1\%$ referenced to 1 kHz</p> <p>Square Wave Response: Rise and fall time, < 200 ns; overshoot $< 5\%$ at full output</p> |
| 4. | <p><u>Strain Gages</u>, DMI Part No. 30615-1 Silicone solid state device with a .5 mil spherical/conical stylus</p> <p>Sensitivity: 10^{-5} in./mV</p> <p>Travel: .070" max. (Approximately)</p> <p>Max. Usable Frequency Range: DC to 30 kHz</p> |

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties (Contd.)

| <u>Item</u> | <u>Description and Significant Parameters</u> |
|-------------|---|
| 5. | <p><u>Strain Gage Meter</u>, DMI Part No. 30617</p> <p>50-0-50 A Panel Meter calibrated to read displacement of strain gage.</p> <p>Output Impedance: 75 ohms</p> <p>Range: .050 - 0 - .050 inches</p> |
| 6. | <p><u>Geophones</u>, Electro-Tech EVS-8A (Vertical) and EVS-8AH Horizontal</p> <p>Frequency: 4.5 cps \pm 1</p> <p>Coil Resistance: 215 ohm</p> <p>(See Figure 3.0.6 for Output vs. Frequency of Geophone.)</p> |
| 7. | <p><u>Three-Channel, Fixed-Gain Linear Amplifier</u>, DMI Part No. 30618</p> <p>Gain: 100</p> <p>Output Swing: 13v p - p</p> <p>Input Impedance: 1.2k Ω</p> <p>Frequency Response: DC to 10 kHz \pm 1 db</p> <p>Temperature Range: 0° C to 70° C</p> <p>Short circuit protected.</p> |

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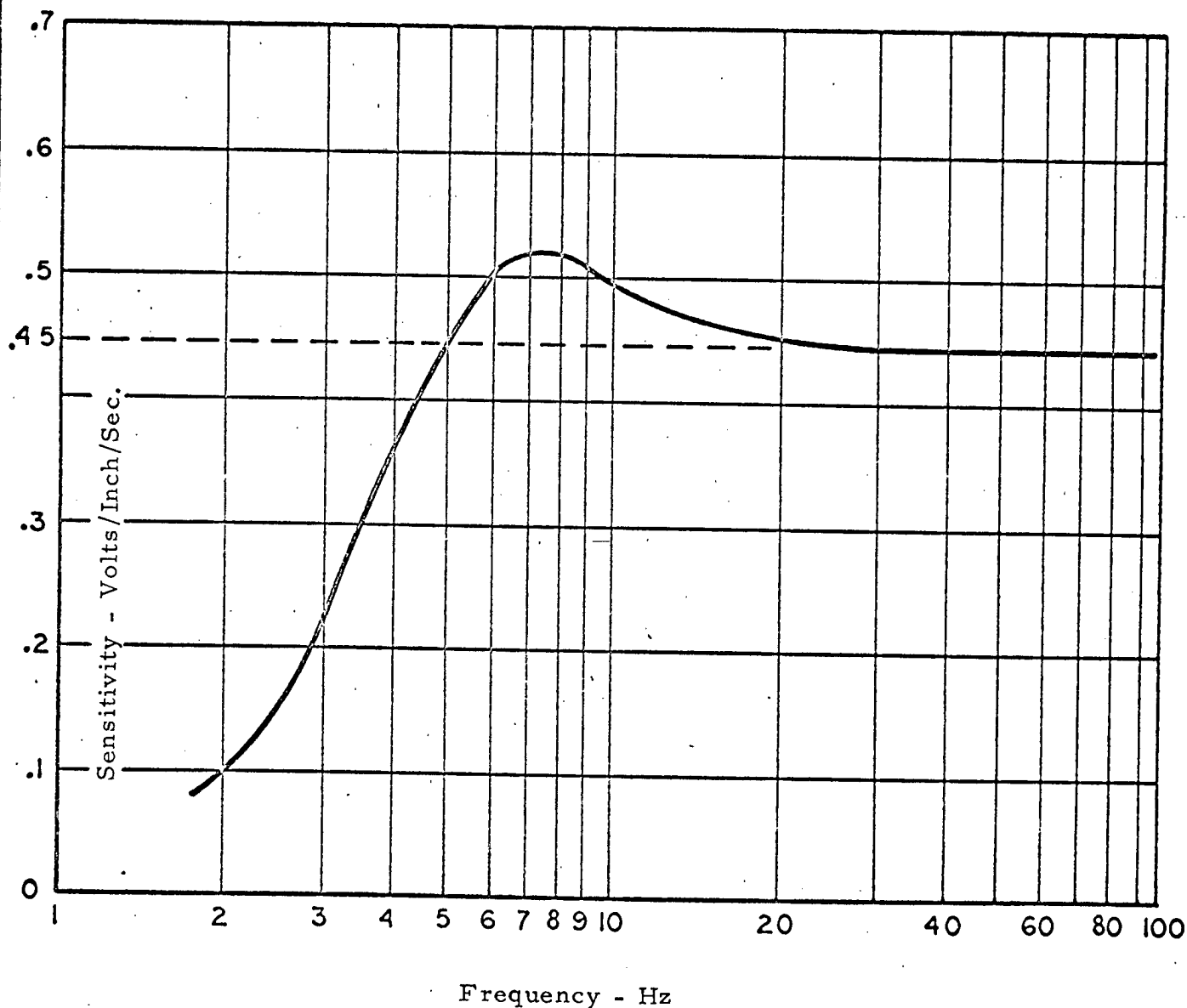
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Figure 3.0.6 Output vs. Frequency of EVS-8 Geophone with DMI Amplifier

Natural Frequency - 4.5 Hz

Coil Resistance - 215 Ohms

.58 Critical Damping

545 Ohm Shunt Resistance (Effective with 1000 Ω resistor in parallel with
DMI Part No. 30618 Amplifier)

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties (Contd.)

Item

Description and Significant Parameters

8. Accelerometer - General Radio Company, Type 1560-P54

An inertia-operated ceramic device which generates a voltage proportional to the acceleration of a vibrating body.

Sensitivity: 700 mV/g, nominal

Temperature Coefficient of Sensitivity: 0.01 db/°C

Resonant Frequency: 5000 Hz

Capacitance: 700 pf

Temperature Range: -18°C to 120°C

Humidity Range: 0% to 100%

9. Preamplifier - General Radio Company, Type 1560-P40

High input impedance, low noise preamplifier of three stage with negative feedback design. Feedback can be switched to obtain a 1:1 or 10:1 voltage gain.

Gain: 1:1 or 10:1 (20 db) \pm 0.3 db at 25°C

Frequency: (0.5V pk - pk open circuit output, -30 to +50°C temperature range)

| | 3 Hz | 5 Hz | 20 Hz | 250 kHz | 500 kHz |
|-----------|------------|--------------|--------------|--------------|---------|
| 1:1 Gain | | \pm 1 db | \pm .25 db | | |
| 10:1 Gain | \pm 3 db | \pm 1.5 db | \pm .25 db | \pm 1.5 db | |

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties (Contd.)

| <u>Item</u> | <u>Description and Significant Parameters</u> |
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| 9. | <p><u>Preamplifier (Contd.)</u></p> <p>Impedance: Input capacitance, 6 pf input resistance $> 500 \text{ M}\Omega$ at low audio frequencies. Output resistance, 1:1 gain, $\approx 20 \Omega$ in series with $3.3 \mu\text{F}$; 10:1 gain, 100Ω in series with $3.3 \mu\text{F}$.</p> <p>Noise: $\leq 2.5 \mu\text{V}$ equivalent input voltage</p> <p>Distortion: $< 0.25\%$ harmonic distortion at audio frequencies, 1% at 1 kHz</p> |
| 10. | <p><u>Sound and Vibration Analyzer, General Radio Co. Model 1564</u></p> <p>This instrument is capable of measuring the amplitude and frequency of components of complex sound and vibration spectra.</p> <p>Frequency Range: 2.5 Hz to 25 kHz in four decade ranges</p> <p>Input Impedance: $25 \text{ M}\Omega$ in parallel with 80 pf</p> <p>Input Voltage Range: 0.3 mV to 30V full scale in 10 db steps</p> <p>Output Voltage: At least 1V open circuit when meter reads full scale</p> <p>Output Impedance: 6000Ω</p> <p>Recording Analyzer: Automatic range switching at the end of each frequency decade allows continuous recording of spectra</p> |

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties (Contd.)

| <u>Item</u> | <u>Description and Significant Parameters</u> |
|-------------|--|
| 11. | <p><u>Dual Beam Oscilloscope</u>, Tektronix Model 502A, and <u>Dumont Oscillograph Record Camera</u>, Type 302, S/N 6249</p> <p>Band Width: DC to 100 kHz (3 db down) at 100 μV/cm, increasing to 1 MHz (3 db down) from 5mV/cm to 20V/cm</p> <p>Deflection Factor: 100 μV/cm to 20V/cm in 17 calibrated steps. Uncalibrated continuously variable to approximately 50V/cm</p> <p>Input R C: 1MΩ in parallel with 47 pf</p> <p>Common Mode Rejection: 50,000:1 (D. C. to 50 kHz)</p> <p>Calibrated Time Base: 1 μ sec/cm to 5 sec/cm</p> <p>Sweep Magnifier: X2, X5, X10, X20</p> <p>External Input: 0.1, 0.2, 0.5, and 2V/cm</p> <p>Amplitude Calibrator: 0.5 mV to 50V, 1 kHz square wave</p> |
| 12. | <p><u>Brush Chart Recorder</u>, Mark 220</p> <p>Number of Channels: 2 analog, 2 event</p> <p>Channel Span: 40mm (50 divisions)</p> <p>Frequency Response: At 50 div: Flat within $\pm 2\%$ of full scale from D. C. to 40 Hz</p> <p>at 10 div: Flat within $\pm 2\%$ of full scale from D. C. to 100 Hz</p> <p>Trace Width: .01 nominal</p> <p>Marking Method: Pressurized fluid</p> |

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3.0 Parameters of Instruments Used in the Investigation/Cure of Vibration Difficulties (Contd.)

| <u>Item</u> | <u>Description and Significant Parameters</u> |
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|-------------|---|

12. Brush Chart Recorder (Contd.)

Chart Speeds: 1, 5, 25, and 125 mm/sec

Input Impedance: 10 M Ω balanced, 5 M Ω each terminal to ground

Measurement Range: 1 mV per div. to 500 VDC full scale

Section 4.1

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger

Six series of tests (Tests Series 11- through 16-) were made on 19, 20, and 21 May 1971. Additional test series (Test Series 18- and 19-) were performed on 2 June and 30 July 1971. These tests, their purposes, and the data obtained are described below, in the order in which they were made. Pertinent original data is reproduced in Appendix 4.1.1.

Test Series 11-

Purpose: Monitor and record the ambient vibrations on the floor of the enlarger room, and the resulting vibrations on various key parts of the equipment.

Method: A vertical geophone, having a 4.5 Hz natural frequency and a known output in volts per inch-per-second at the frequencies of interest, was used to monitor ambient vibrations of the floor. It was coupled firmly to the floor with double-sided tape. A GRC Type 1560-P54 Accelerometer, with GRC Type 1540-P40 Pre-Amplifier, was used to measure vibrations on the floor and at various points on the equipment simultaneously with the monitoring of vibrations on the floor. On the records, the geophone signal (velocity) is noted as \dot{X} , and the accelerometer record (acceleration) is noted as \ddot{X} .

Test 11-1 Velocity and acceleration recorded side by side, in the vertical direction, simultaneously, at a point on the floor near the right front foot of the enlarger. For the remainder of the tests in this series, the geophone remained at this spot to monitor the floor ambient vibrations while the accelerometer was used at various other points of significance on the equipment and its supports. A GRC Type 1564 Sound and Vibration Analyzer, with band-pass filter set on 1/10-octave band width, was used to condition the accelerometer output for observation of response at various frequencies in a sweep from 10 Hz to 250 Hz. Test 11-1 was a preliminary set-up check and contains no significant data.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Test 11-2 Acceleration record on floor. Velocity on floor. Vertical directions. Sweep frequencies. Tests begun on 19 May 1971.

Test 11-3 Repeat 11-2 at increased record sensitivity.

Test 11-4 Acceleration record on top of right front isolated foot. Velocity on floor. Vertical directions. Sweep frequencies.

Test 11-5 Acceleration, vertical, on film gate. Velocity, vertical on floor. Enlarger brake on, small blower on. GRC calibration observed to be incorrect during frequency sweep.

Test 11-6 Repeat above test 11-5, with correct GRC calibration. Note in all such records that the large signal pulse observed at 25 Hz is due to the noise from the GRC range selector switch being changed, and should be disregarded.

Test 11-7 Repeat test of 11-5, but with enlarger brake on, small blower off.

Test 11-8 Same as 11-7, with increased record sensitivity.

Test 11-9 Same as 11-5, but with enlarger brake off, and blower off.

Test 11-10 Repeat 11-9.

Test 11-11 Both records on floor again, near front right foot of enlarger. This test was to recheck ambient conditions, 20 May 1971. All enlarger power is off.

Test 11-12 Repeat test 11-11, with lower record sensitivity, to evaluate portion near 30 Hz, where test 11-11 went off scale.

Test 11-13 Y-axis acceleration, frequency sweep, at film gate, with vertical velocity monitor on floor. Enlarger brake off, blower off.

Test 11-14 Same as 11-13, enlarger brake on, blower off.

Test 11-15 Same as 11-13, enlarger brake on, blower on.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Test 11-16 Same as 11-15, at lower record sensitivity.

Test 11-17 X-axis acceleration, frequency sweep, at film gate, with vertical velocity monitor on floor. Enlarger brake and blower on.

Test 11-18 Same as 11-17, with enlarger brake and blower off.

Test 11-19 Repeat of 11-17, brake and blower on, at lower record sensitivity to keep 57 Hz peak signal on scale.

Test 11-20 (Also labeled AMBI-5, dated 21 May 1971) A length of the unfiltered, ambient velocity vibration record from the vertical geophone on the floor, located next to the enlarger foot, was made for the purpose of future digitization and power-spectrum analysis.

Test Series 12-

Purpose: Determine the natural frequency and damping ratio of the 10X-20X-40X Enlarger's isolated mounting.

Method: Geophones and an accelerometer were mounted on the isolated foot of the enlarger. Recordings were made of the response of the mount to an impulse applied vertically over the isolator. The best record obtained for computation of frequency and damping was that from the unfiltered geophone, top record, Test 12-4.

Test 12-1 Unfiltered geophone vs. filtered geophone.

Test 12-2 Same as 12-1, better impulse, enlarger brake off.

Test 12-3 Same as 12-2, with higher record sensitivity.

Test 12-4 Unfiltered geophone vs. accelerometer. Brake on. This record of velocity response was used for computations.

Test Series 13-

Purpose: Use inertial measurements (velocity, geophones) to determine displacements between stations on the enlarger that would indicate "rocking" or other significant distortions of the optical path.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Method: Pairs of matched, calibrated geophones were placed on opposite ends of structural members so arranged that they could undergo relative angular motion disturbing to the optics. The geophone polarities were wired so that "in-phase" motions would record "in-phase". The geophone responses to ambient disturbances going on in the building were displayed on a two-channel oscilloscope and photographed. The several locations for the paired geophones are shown on Sketch Photo A-4c, and A-4d, of the original data. These locations are numbered RD-1, RD-2, RD-3 and RD-4. Oscilloscope photographs of the resulting data are as follows:

Test 13-1 Vertical geophones at location RD-1, with fan on.

For all tests until further note; scope amplitude was 1 mV per cm, and scope sweep rate was 0.1 sec per cm.

Test 13-2 Same as 13-1, with fan off.

Test 13-3 Vertical geophones at locations RD-2, with fan on.

Test 13-4 Same as 13-3, with fan off.

Test 13-5 Vertical geophones at locations RD-3, with fan on.

Test 13-6 Same as 13-5, with fan off.

Test 13-7 Same as 13-6.

Test 13-8 Same as 13-6.

Test 13-9 Horizontal geophones at locations RD-4, with fan on. Note scope amplitude is 2 mV per cm, sweep 0.1 sec. per cm.

Test 13-10 Same as 13-9, with fan off.

Test 13-11 Same as 13-10, but with scope fast sweep 0.1 sec. per cm.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Test Series 14-

Purpose: These tests used inertial measurements to approximate the responses of the film gate structure and the paper platen structure to ambient disturbances and external impulses. Locations are shown in sketch photo CAL-1.

Method: Both the accelerometer and the geophone were tested as transducers for this purpose. The geophones were selected as having less susceptibility to electrical noise in the all-pass mode of operation intended. The various tests are listed below:

Test 14-A Calibration. Comparison of geophone and accelerometer, in Y-direction, at film gate support. Remainder of records are geophone only.

Test 14-1 Response at film gate, Y-direction.

Test 14-2 Response at film gate, Z-direction.

Test 14-3 Response at film gate, X-direction.

Test 14-4 Repeat of test 14-2.

Test 14-5 Response at platen, Z-direction.

Test 14-6 Response at platen, X-direction.

Test 14-7 Repeat of test 14-6.

Test 14-8 Response at platen, Y-direction.

Test Series 15-

Purpose: Having observed various low-natural-frequency responses of structural elements in the enlarger, the purpose of the Series 15- tests was to record the responses at the lens support structure to single impulses (of the press-and-release type) at various points of application.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Method: The location of the recording geophones and the point of impulse on the equipment is shown in sketch photo NF-1 of the original data. The specific tests are as listed below:

Test 15-1 Structural response at (1) on the lens support structure in the X-direction, with the film backplate centered.

Test 15-2 Same as 15-1, but with the backplate fully to the rear.

Test 15-3 Responses at (2) and (3), high and low on the backplate, in the Y-direction, backplate fully to the rear.

Test 15-4 Same as 15-3.

Test 15-5 Same as 15-3, with the backplate centered.

Test 15-6 Same as the test of 15-1 and 15-2, but at high record speed of 125mm per sec., to be sure of the frequency determination.

Test 15-7 Responses at (2) backplate, and (7) film gate, in the Z-direction, due to a Y-direction impulse.

Test 15-8 Responses at (2) backplate, and (5) film gate, in the Z-direction, due to a Z-direction impulse.

Test Series 16-

Purpose: This was a single test, made to determine the spring rate of the front isolator support in the vertical direction.

Method: A precision dial extensometer was placed to measure the dimensional movement between the isolated frame and the concrete slab floor, at the right, front foot of the enlarger. The deflection produced by the imposition of a 190-pound mass, man's weight, on the isolated portion of the structure directly over the support, was measured. From this, the spring rate of the individual mount was approximated and found to be 2,000 lb per inch.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)Test Series 18-

Purpose: This series of tests was designed to measure the responses of the enlarger's film gate support structure to disturbances caused by driving the floor slab with a vibration generator at approximately 10 Hz. This is the predicted worst-case frequency of the [] report, resulting from the transmission of external disturbances through the soil and building columns. The floor was driven at one-half of the worst-case displacement predicted by the [] report, or 35 microinches, zero-STAT to-peak.

Method: Two vertical geophones are used as sensors. The signal from one, which remains on the floor, is recorded unfiltered as an indication of the driving level. The signal from the second is the response data of interest, and is filtered at 10 Hz, with a 1/3-octave band-pass width, except as noted. Recordings were made as follows:

Test 18-a-1 Response at floor, approximately 11 Hz.

Test 18-a-2 Response at floor, approximately 10-1/8 Hz.

Test 18-b-1 Vertical response at film gate, filtered at 10 Hz.

Test 18-b-2 Vertical response at film gate, unfiltered.

Test 18-c-1 Horizontal response, X direction, at film gate, filtered 10 Hz.

Test 18-c-2 Horizontal response, X direction, at film gate, unfiltered.

Test 18-d-1 Horizontal response, Y direction, at film gate, filtered 10 Hz.

Test 18-d-2 Horizontal response, Y direction, at film gate, unfiltered.

Note, in cases where the response is unfiltered, the driving force monitor is filtered, and is oriented in the same direction as the response geophone.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Test Series 19a through 19e

Purpose: Monitor and record vibrations in the floor, and simultaneously at various points on the equipment under ambient disturbance conditions, and while the floor is being driven in the vertical mode at the predicted worst-case amplitude levels of the at steady-state frequencies of 10, 18, and 25 Hz. STAT

Method: A vertical geophone located on the floor directly beneath the enlarger platen is used to monitor levels of vibration in the floor, \dot{Z}_D . A second geophone, vertical or horizontal as appropriate to the case, is used to record vibrations at the following points on the enlarger: subscript "C", the lens and filmgate assembly; subscript "E", the platen. "Z" indicates a vertical velocity component, and "X" indicates a horizontal velocity component. One record is always \dot{Z}_D , the floor:

Test 19a-1 Unfiltered ambient \dot{Z}_C .

Test 19a-2 Unfiltered ambient \dot{X}_C .

Test 19a-3 Repeat 19a-2 with larger scale of sensitivity for \dot{Z}_D . This sensitivity is used for all subsequent recordings.

Test 19a-4 Unfiltered ambient \dot{X}_E .

Test 19a-5 Unfiltered ambient \dot{Z}_E .

Test 19b-1 Drive 10Hz, record \dot{Z}_E .

Test 19b-2 Drive 10Hz, record \dot{Z}_C .

Test 19b-3 Drive 10Hz, record \dot{X}_C .

Test 19b-4 Drive 10Hz, record \dot{X}_E .

Test 19c-1 Test for floor resonance, found it to be approximately 25 Hz.

Test 19d-1 Drive 18Hz, record \dot{X}_E .

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Test 19d-2 Drive 18Hz, record \dot{X}_C .

Test 19d-3 Drive 18Hz, record \dot{Z}_C .

Test 19d-4 Drive 18Hz, record \dot{Z}_E .

Test 19e-1 Drive 25Hz, record \dot{Z}_E .

Test 19e-2 Drive 25Hz, record \dot{Z}_C .

Test 19e-3 Drive 25Hz, record \dot{X}_C .

Test 19e-4 Drive 25Hz, record \dot{X}_E .

Test Series 19f

Purpose: Measure impulse reactions and record, for lens and filmgate assembly and for platen assembly in order to get relative rates of horizontal motion and response at the two ends of the optical path. Also investigate the horizontal response of the lens and filmgate assembly to low-frequency floor excitation, 5 Hz.

Method: With instrumentation setup same as for previous tests of the 19- series, make press-and-release impulses on the enlarger structure and record its responses.

Tests 19f-1 and 19f-2

Impulse tests on lens mount, \dot{X}_C records.

Tests 19f-3 and 19f-4

Impulse tests on platen, \dot{X}_E records.

Test 19f-5 Drive at 5Hz, record \dot{X}_C at lens and filmgate assembly.

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4.1 Detail Description, Vibration Tests - Kodak 10X, 20X, 40X Enlarger (Contd.)

Test Series 19g

Purpose: To measure the actual photograph reproduction performance of the 10X, 20X, 40X Enlarger, as represented by its ability to reproduce the image of a standard Air Force resolution target on film, under normal ambient vibration conditions, and while the floor is being excited to predicted worst-case levels, at frequencies of 5, 10, 18, and 25Hz. The tests are designed to demonstrate whether there will be any loss in resolution at any of the excitation frequencies under worst-case conditions.

Method: With instruments and vibration driver set up as for the previous tests of Series 19-, make photographic enlargements on film, for each of the vibration levels selected. The film used is Fine Grain Positive No. 7302, Eastman Kodak and Company.

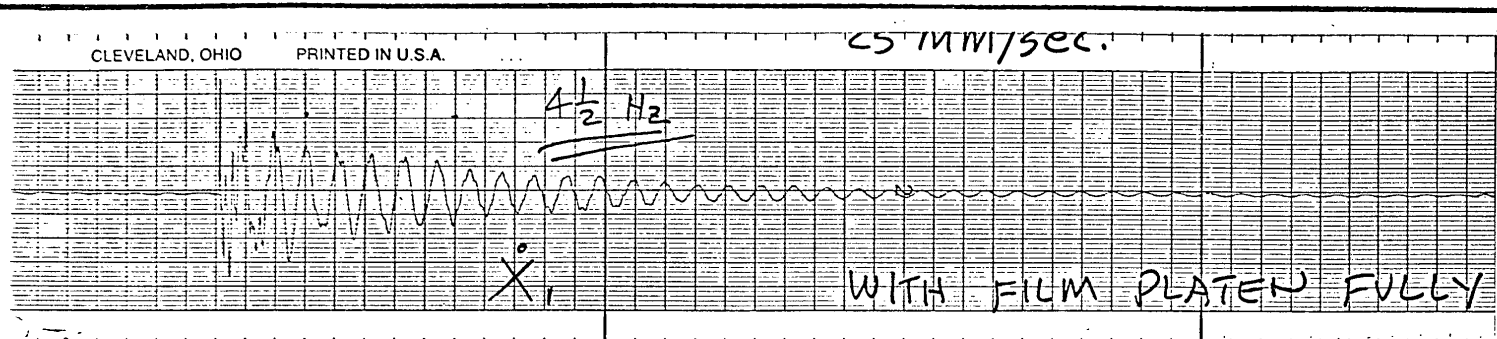
Test 19g-1 Room under normal ambient conditions. Make several test exposures to optimize exposure, time, focus development, and other parameters, in order to produce highest possible resolution. Use identical photographic parameters for all following tests. (The optimum film for this test has one V-notch in its edge.)

Test 19g-2 Exposure at 5Hz floor drive (2 V-notches in film).

Test 19g-3 Exposure at 10Hz floor drive (3 V-notches in film).

Test 19g-4 Exposure at 18Hz floor drive (4 V-notches in film).

Test 19g-5 Exposure at 25Hz floor drive (5 V-notches in film).

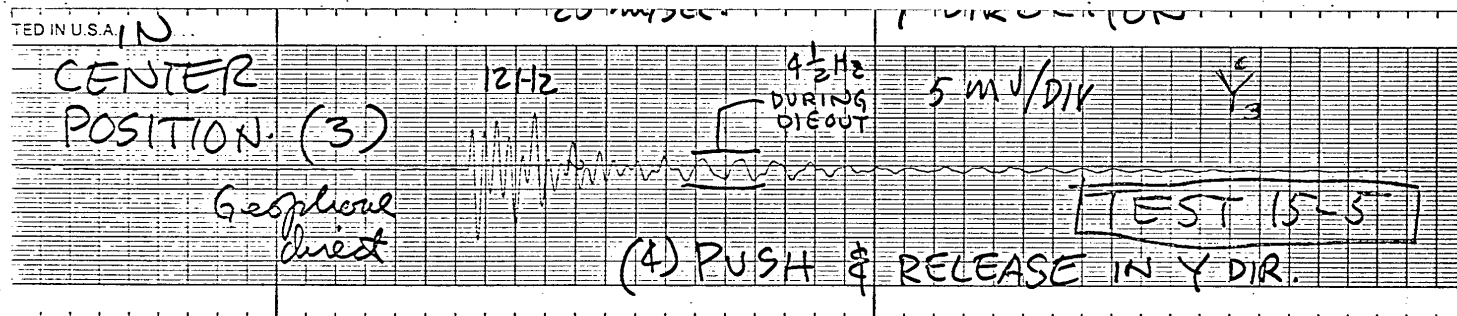


Test 15-2

10X, 20X, 40X Enlarger, 21 May 1971, 1100 hrs

Response of lens mount and film gate support to "push and release" impulse with backplate at rear position. Impulse in X direction and record in X direction.

Geophone record X₁ at position ①, 5 mV/mm = 11×10^{-4} inches/second.



Test 15-5

10X, 20X, 40X Enlarger, 21 May 1971, 1100 hrs

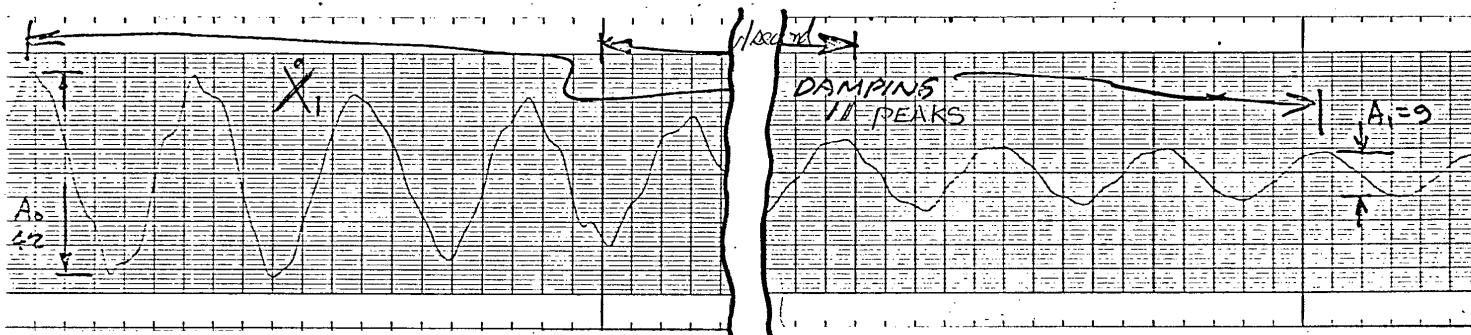
Response of lens mount and film gate support to "push and release" impulse with backplate at center position. Impulse and record in Y direction.

Geophone record Y₃ at position ③, 5 mV/mm = 11×10^{-4} inches/second.

Figure 4.1.1 Test 15-2 & 15-5

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Test 15-6

10X, 20X, 40X Enlarger, 21 May 1971, 1100 hrs

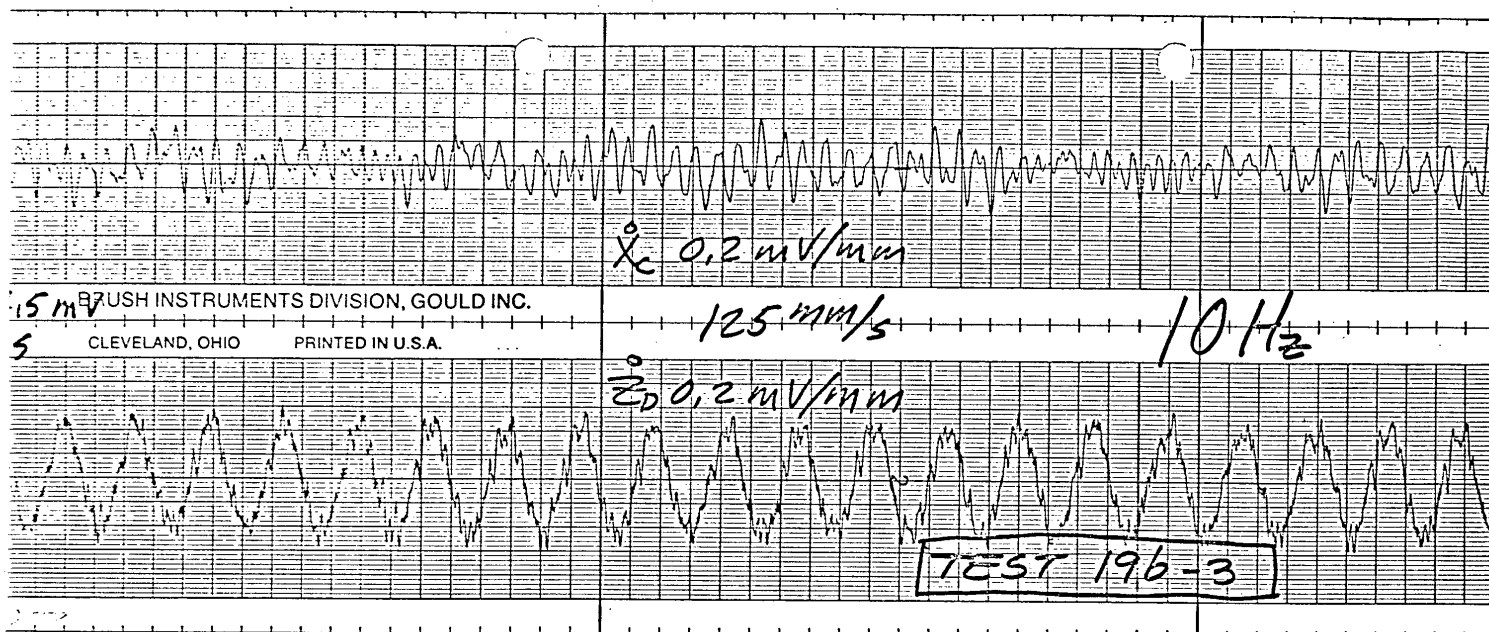
Response of lens mount and film gate support to "push and release" impulse with backplate at rear position. Impulse and record in X direction.

Geophone record X_1 , at position ①, $5\text{mV/mm} = 11 \times 10^{-4}$ inches/second.

Part of record not reproduced. Gap can be recovered by 1 second time marks.

Total number of cycles counted from A_0 to A_1 is 11 cycles.

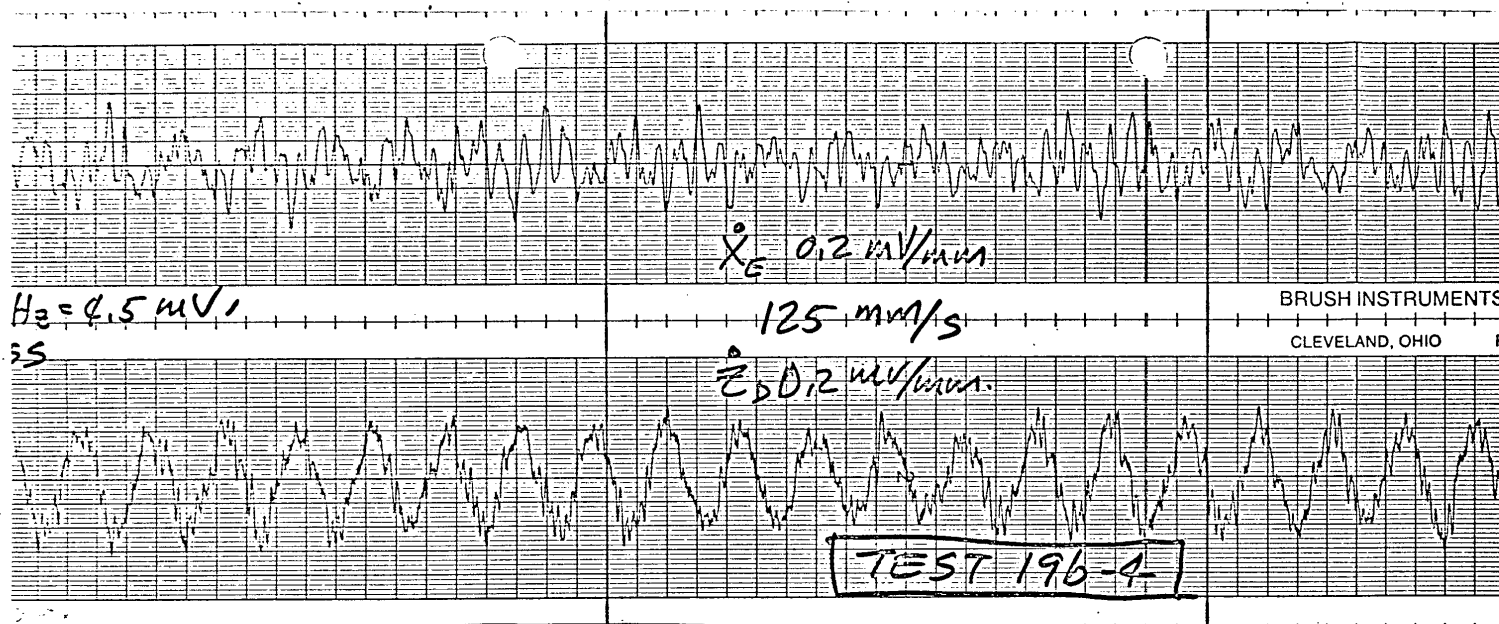
Chart speed 125 mm/second to define oscillations better.



Test 19b-3

10X, 20X, 40X Enlarger, 30 July 1971, 1000 hrs
 Response of lens and film gate support at point C in X direction to 10 Hz
 "worst case" floor drive.
 Geophone record \dot{X}_C , 0.2 mV/mm = 44×10^{-5} inches/second
 Geophone record \ddot{Z}_D , 0.2 mV/mm = 44×10^{-5} inches/second
 Chart speed 125 mm/second

Figure 4.1.1 Test 19b-4



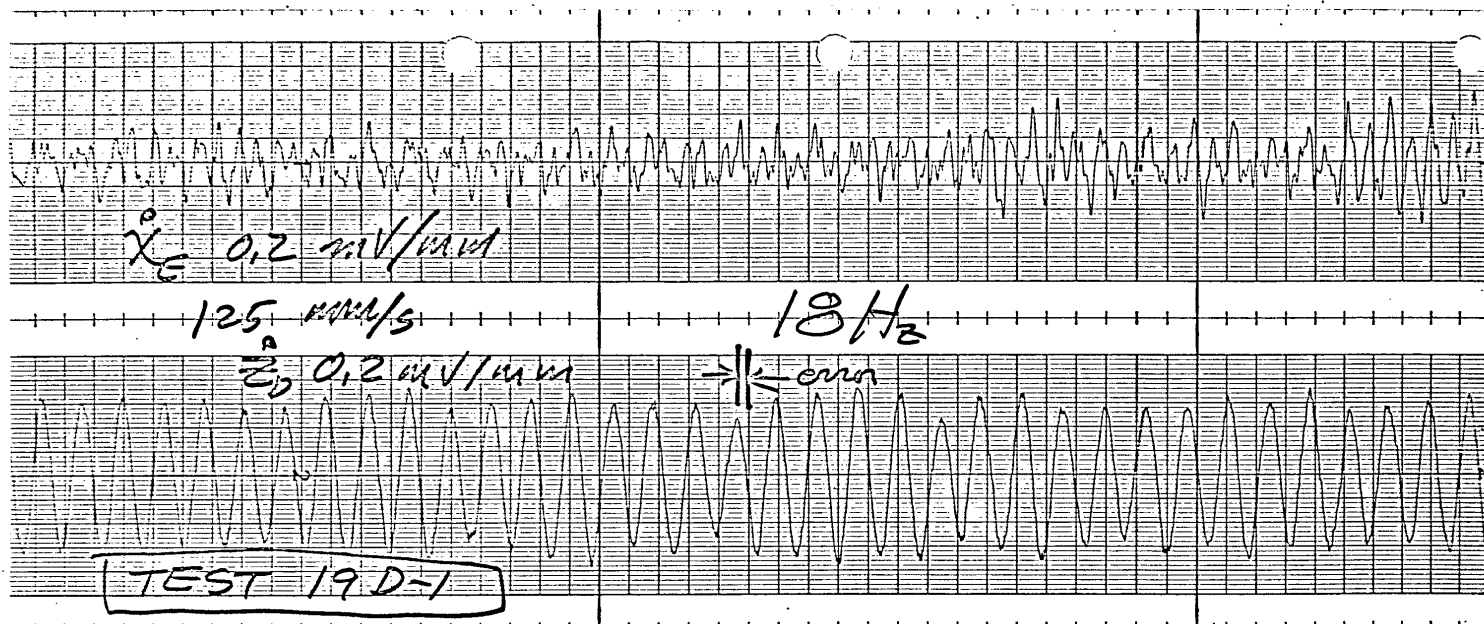
Test 19b-4

10X, 20X, 40X Enlarger, 30 July 1971, 1000 hrs
 Response easel at point E in X direction to 10 Hz "worst case" floor drive
 Geophone record of \ddot{X}_e , 0.2 mV/mm = 44×10^{-5} inches/second
 Geophone record of \ddot{Z}_d , 0.2 mV/mm = 44×10^{-5} inches/second
 Chart speed, 125 mm/second

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Figure 4.1.1 Test 19d-1



Test 19d-1

10X, 20X, 40X, Enlarger, 30 July 1971, 1000 hrs

Response of easel at point E in X direction to 18 Hz "worst case" floor drive at point D

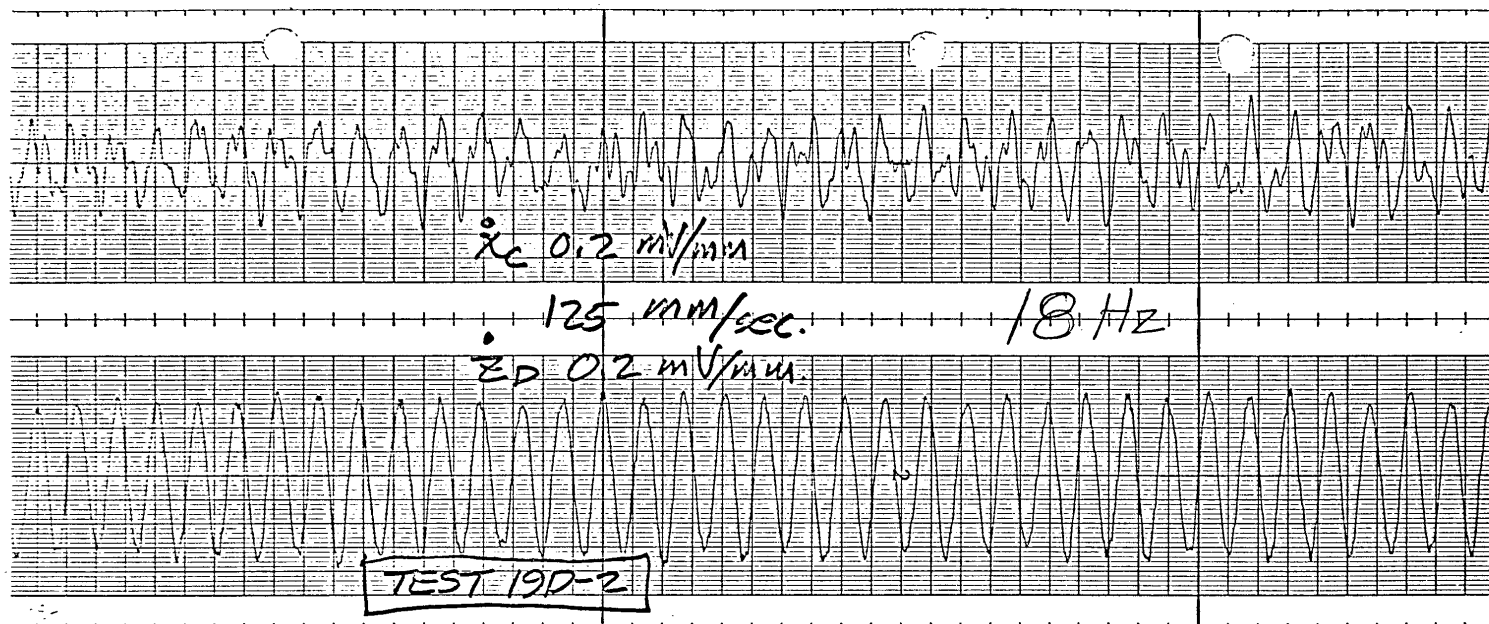
Geophone record of \dot{X}_E , 0.2 mV/mm = 44×10^{-5} inches/second

Geophone record of \dot{Z}_D , 0.2 mV/mm = 44×10^{-5} inches/second

Chart speed 125 mm/second

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Test 19d-2

10X, 20X, 40X Enlarger, 30 July 1971, 1030 hrs

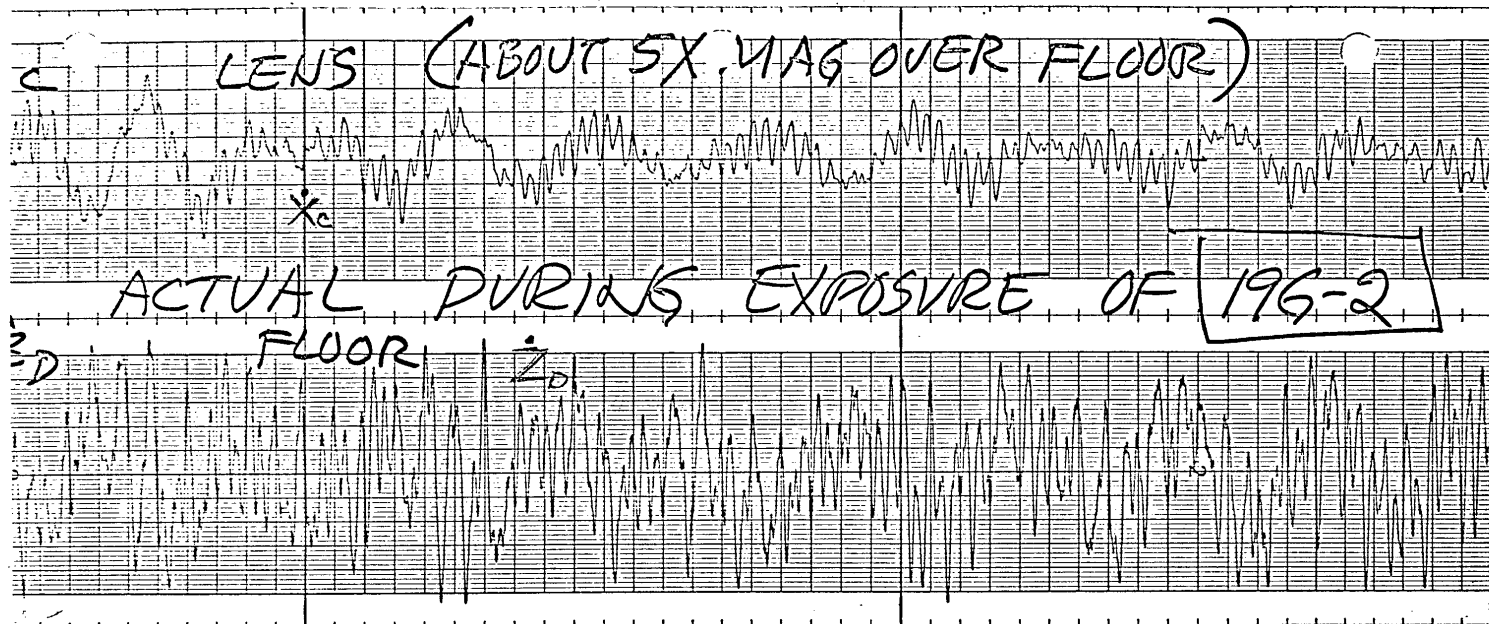
Response of lens and film gate support at point C in X direction to 18 Hz
"worst case" floor drive

Geophone record \dot{x}_c , 0.2 mV/mm = 44×10^{-5} inches/second

Geophone record \dot{z}_d , 0.2 mV/mm = 44×10^{-5} inches/second

Chart speed 125mm /second

Figure 4.1.1 Test 19g-2



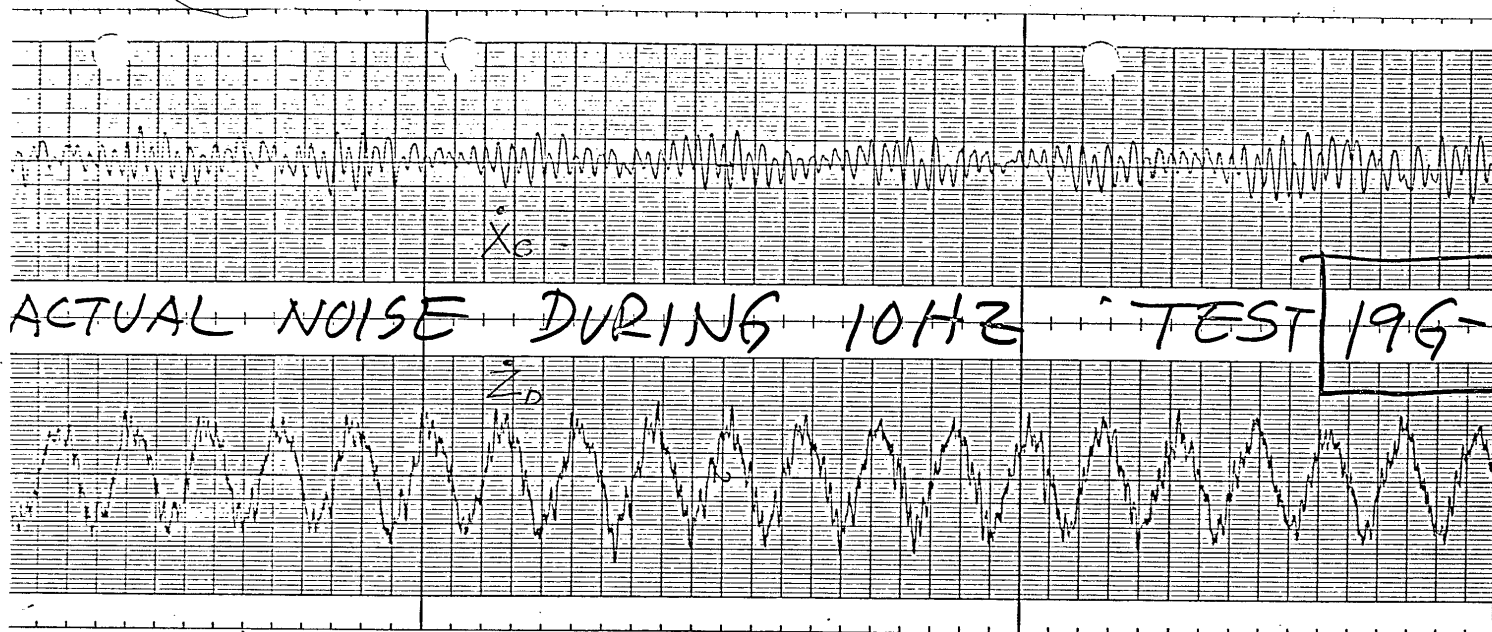
Test 19g-2

10X, 20X, 40X, Enlarger, 30 July 1971, 1100 hrs.
 Response of lens and film gate support at point C in X direction to 5 Hz floor drive at low level (same as driver setting for 10 Hz).
 Geophone record of \ddot{X}_c , 0.2 mV/mm = 44×10^{-5} inches/second
 Geophone record of \ddot{Z}_d , 0.02 mV/mm = 4.4×10^{-5} inches/second
 Record made during exposure of resolution target.

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Figure 4.1.1 Test 19g-3



Test 19g-3

10X, 20X, 40X Enlarger, 30 July 1971, 1100 hrs

Response of lens and film gate support at point C in X direction to 10 Hz

"worst case" floor drive

Geophone record of \dot{X}_c , 0.2 mV/mm = 44×10^{-5} inches/second

Geophone record of \dot{Z}_d , 0.2 mV/mm = 44×10^{-5} inches/second

Record made during exposure of resolution target.

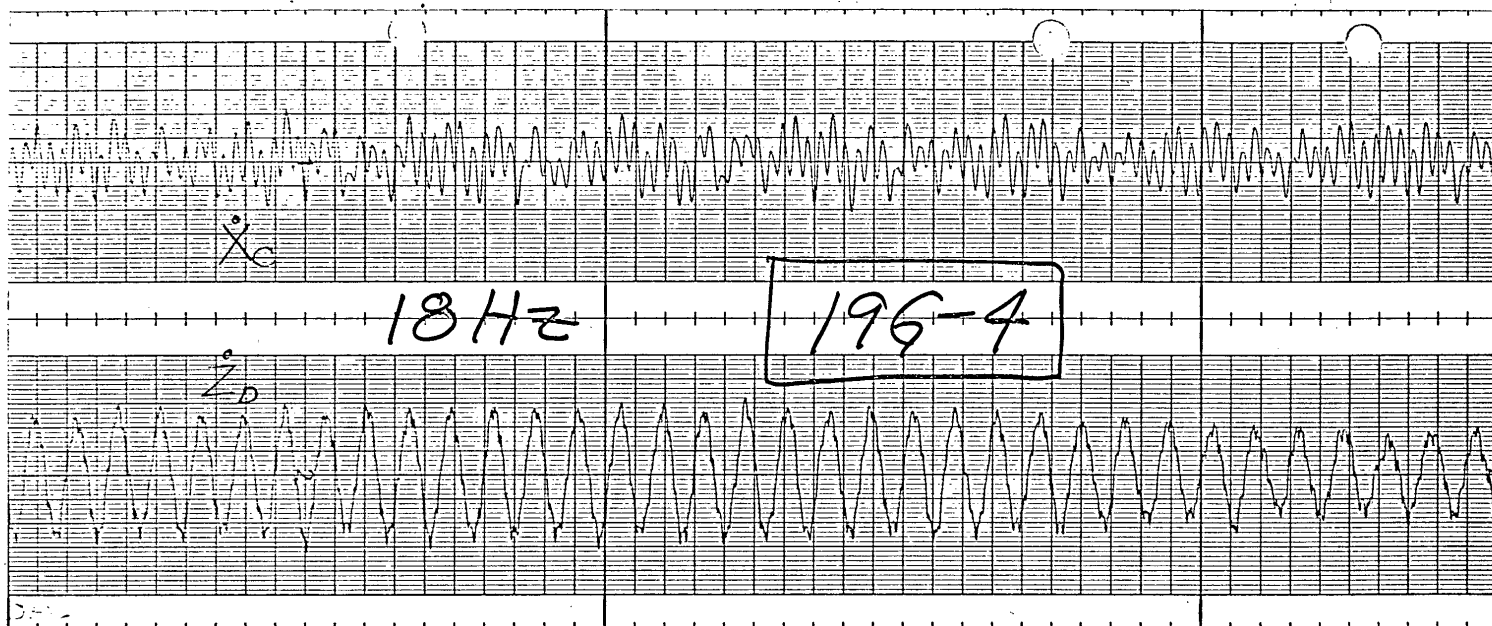
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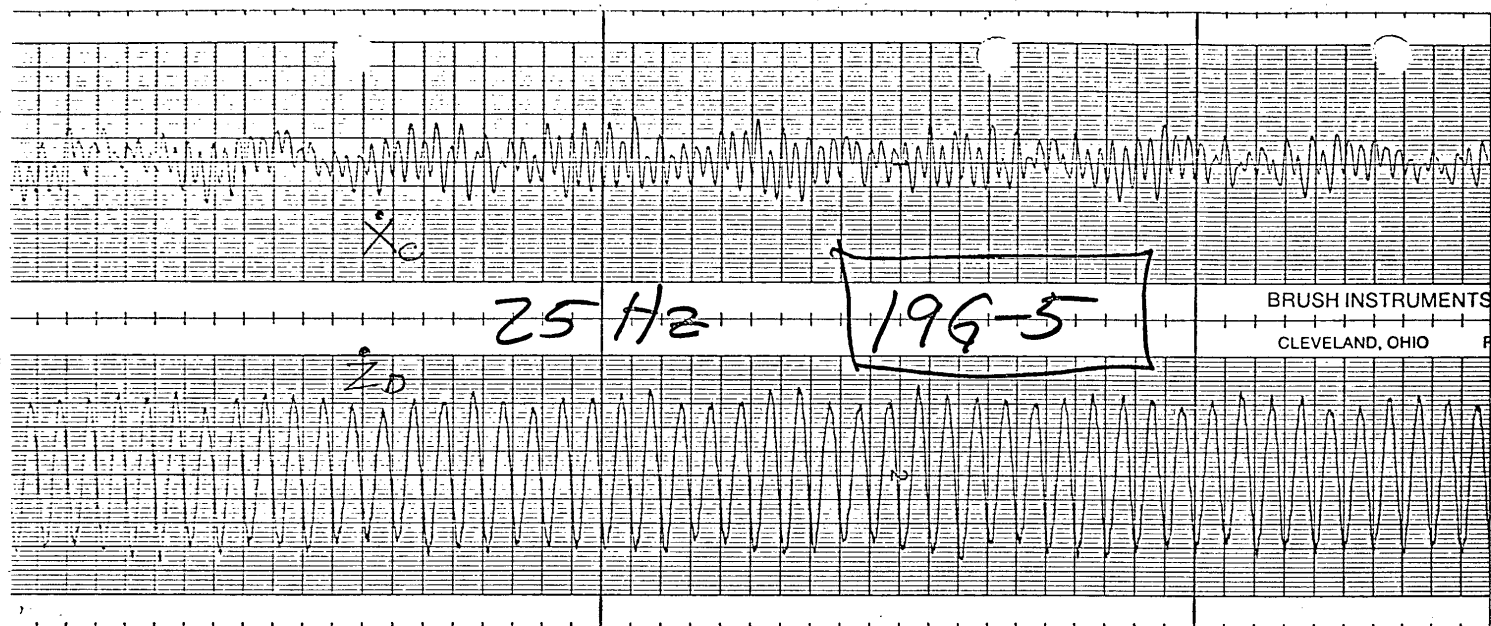


Test 19g-4

10X, 20X, 40X, Enlarger, 30 July 1971, 1100 hrs
Response of lens and film gate support at point C in X direction
to 18Hz "worst case" floor drive
Geophone record of \dot{X}_c , 0.2 mV/mm = 44×10^{-5} inches/second
Geophone record of \dot{Z}_d , 0.2 mV/mm = 44×10^{-5} inches/second
Record made during exposure of resolution target

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Figure 4.1.1 Test 19g-5



Test 19g -5

10X, 20X, 40X Enlarger, 30 July 1971, 1100 hrs

Response of lens and film gate support at point C in X direction to 25 Hz

"worst case" floor drive

Geophone record of X_c , 0.2 mV/mm = 44×10^{-5} inches/second

Geophone record of Z_d , 0.2 mV/mm = 44×10^{-5} inches/second

Record made during exposure of resolution target

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator

Two test series (Series 21 and 22) were made on 24 and 25 May and two additional tests (Series 23 and 24) were completed on 29 July 1971. During all tests, the equipment and its room were in normal operating configuration, and the surrounding area was in normal operation. Pertinent original data is reproduced in Appendix 4.2.1.

Test Series 21-

Purpose: Measure the typical ambient noise environment for the machine under various operating conditions, and the responses of the equipment at locations significant to the optical performance.

Method: Matched, calibrated geophones were used to transduce and record vibrations. One geophone was always kept on the floor, to measure ambient disturbances. The other geophone was placed at successive points of interest. After preliminary recording, the technique of sweeping frequency from 2.5 Hz to 200 Hz, using the band-pass filter of the GRC Analyzer set on 1/3-octave band width, was used to give approximate, or qualitative, spectrum analyses. The tests of this series were as follows:

Test 21A-Step a. Using the vertical geophones (Z axis) with one geophone on the floor, and the other on the equipment's isolated foot pad, the set-up was observed on the oscilloscope and checked. No record was made.

Test 21A-Step b. With the setup of Step a., the door to the room was slammed. Records were made of the response on floor and bench. The mount pad apparently filters high frequencies, but transmits the 31-Hz and lower disturbances.

Test 21A-Step c. Similar to Step b., but with response geophone located on top of instrument bridge. An additional, slight amplification of the 31-Hz frequency is observed.

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

Test 21A-Step d. Sweep frequency analysis of instrument response at top of bridge, with monitoring of ambient disturbances in floor. (Three records not valid. Stopped to revise scan technique to avoid turning frequency selector dial while recording is being made.) Fourth record is valid.

Test 21A-Step e. Sweep frequency analysis of ambient noise in floor. The vertical geophones are still being used (Z axis).

Test 21A-Step f. Sweep frequency analysis of response inside table foot, on top of damper pad. (Z direction)

Test 21A-Step g. Sweep frequency analysis of response on top of table, next to right front foot of comparator structure. (Z direction)

Test 21B - This test continued the same type of analysis as in 21A, except that horizontal directions of motion were investigated.

Test 21B-Step a. Monitor ambient \ddot{X} and \ddot{Y} vibrations simultaneously on floor of room near the comparator.

Test 21B-Step b. Monitor \ddot{Y} on floor during the following tests. Sweep frequency analysis of response in Y direction on mount pad. A detailed scan was also made in this setup (5 to 25 Hz in 1-Hz steps).

Test 21B-Step c. Monitor \ddot{X} on floor, sweep frequency \ddot{X} on mount pad.

Test 21B-Step d. Monitor \ddot{X} on floor, sweep frequency \ddot{X} on floor.

Test 21B-Step e. Monitor \ddot{Y} on floor, sweep frequency \ddot{Y} on floor.

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

Test 21B-Step f. Monitor \dot{Y} on floor, sweep frequency \dot{Y} on top of table, next to comparator right front foot.

Test 21B-Step g. Monitor \dot{X} on floor, sweep frequency \dot{X} on table top next to comparator right front foot.

Test 21B-Step h. Monitor \dot{X} on floor, sweep frequency \dot{X} at top of comparator bridge structure.

Test 21B-Step i. Monitor \dot{Y} on floor, sweep frequency \dot{Y} at top of comparator bridge structure. This was the last test of the day on 24 May.

(Resume test program at 9:00 am, 25 May 1971.)

Test 21B-Step j. Monitor \dot{Z} on floor, sweep frequency \dot{Z} at instrument platen.

Test 21B-Step k. Monitor \dot{Z} on top of bridge structure, sweep frequency \dot{Z} at instrument platen.

Test 21B-Step l. Monitor \dot{Y} on top of bridge structure and \dot{Y} on instrument platen while room door is slammed (shut firmly).

Test 21B-Step m. Monitor \dot{Y} on bridge, sweep frequency \dot{Y} on instrument platen.

Test 21B-Step n. Monitor \dot{X} on bridge, \dot{X} on platen while door to room is slammed.

Test 21B-Step o. Monitor \dot{X} on bridge, sweep frequency \dot{X} on platen.

Test 21B-Step p. Monitor \dot{Y} on instrument platen, record \dot{Z} on eyepiece structure while door to room is slammed.

Test 21B-Step q. Monitor \dot{Y} on platen, sweep frequency \dot{Z} on eyepiece.

Test 21B-Step r. Monitor \dot{X} on platen, record \dot{X} on eyepiece while door to room is slammed.

Test 21B-Step s. Monitor \dot{X} on platen, sweep frequency \dot{X} on eyepiece.

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

Test Series 22-

Purpose: Determine the relative displacements between the instrument eyepiece and the image platen under ambient conditions, and in response to selected excitation frequencies.

Method: Display the signals from two displacement transducers on the oscilloscope and record the oscilloscope traces on Polaroid photographs, for each test step. Calibration for the transducers is 1 mV as displayed on scope, equals 10 microinches displacement. If voltage is read peak-to-peak, the displacement is peak-to-peak.

Test 22a. Measure relative displacement in the X direction between points on the platen and on the binocular eyepiece, relative to a fixed base on the comparator. Display the signals produced under ambient disturbance conditions on the oscilloscope and record on scope photo (22-a.). The signal from the eyepiece shows a predominant 120-Hz vibration, while that from the platen shows some lower frequencies, superimposed by extremely high-frequency (audio-range) vibrations of very small magnitude. These relatively low-level vibrations will be disregarded in the subsequent driven-excitation tests.

Test 22b. With same setup as test 22a, mount a vertical geophone on the mount foot pad, near the floor, and a monitor geophone on the floor as a check on incoming ambient disturbances. Record both signals on the Brush recorder, while driving the equipment with a small caladyne oscillator on the left front corner of the table top (not the instrument base casting). Purpose is to determine relative displacement responses of the instrument optical path to sinusoidal inputs, steady-state, at known frequencies and amplitudes. Tests were as follows:

22-b-1-(1) Drive in Z direction, 10 Hz, record geophone signals.

22-b-1-(2) Drive in X direction, 10 Hz, record geophone signals.

22-b-1-(3) Drive in X direction, 10 Hz, photograph signals from relative displacement transducers, scope photo 22-b-1-(3).

22-b-1-(4) Drive in X at 30 Hz, record geophone signals.

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

- 22-b-1-(5) Drive in X at 44 Hz, record geophone signals.
- 22-b-1-(6) Record geophone signals with only ambient disturbance.
- 22-b-1-(7) Drive in X at 44 Hz and photograph signals from relative displacement transducers, scope photo 22-b-1-(7).
- 22-b-1-(8) Drive in Z at 30 Hz, record geophone signals.
- 22-b-1-(9) Drive in Z at 44 Hz, record geophone signals and photograph relative displacement signals from the transducers, scope photo 22-b-1-(9).
- 22-b-1-(10) Drive in Z at 121 Hz, record geophone signals and photograph relative displacement signals from the transducers, scope photo 22-b-1-(10).
- 22-b-1-(11) Drive in Y direction at 13 Hz, record geophone signals and photograph relative displacement signals from the transducers, scope photo 22-b-1-(11).
- 22-b-1-(12) Drive in Y direction at 44 Hz, record geophone signals and photograph relative displacement signals from the transducers, scope photo 22-b-1-(12).

Note that in the above tests, the particular frequencies chosen as drive inputs were frequencies where above normal response was observed at the mount pad geophone, as the input drive frequency was gradually increased.

Test 22c. For this test, the procedure of 22b. was followed except that the position of the relative displacement transducers was changed to measure the relative displacement in the Y direction between the platen and the binocular eyepiece. This means that the transducer on the platen was measuring Y-displacements and that on the eyepiece was measuring Z-displacements, since the optical path is folded 90-degrees by a 45-degree first-surface mirror. These runs were again at frequencies where above normal responses were observed at the geophone on the mount pad, as follows:

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

- 22-c-(1) Drive in Z direction at 178 Hz, record geophone responses and photograph displacement transducer signals, scope photo 22-c-(1).
- 22-c-(2) Note: At this point it was decided wise to shift the measurement of response with the geophone from the mount pad, to the top of the instrument bridge.
- Repeat test 22-c-(1) with response at top of bridge. All further tests have the response monitored at top of bridge. Scope photo not required, same as 22-c-(1).
- 22-c-(3) Drive in Z direction at 96 Hz, scope photo 22-c-(3).
- 22-c-(4) Drive in Z direction at 85 Hz, scope photo 22-c-(4).
- 22-c-(5) Drive in Z direction at 44 Hz, scope photo 22-c-(5).
- 22-c-(6) Drive in Y direction at 44 Hz, scope photo 22-c-(6).
- 22-c-(7) Drive in Y direction at 85 Hz, scope photo 22-c-(7).
- 22-c-(8) Drive in X at 95 Hz, scope photo 22-c-(8). No other significant resonances or responses found in the sweep through various drive frequencies in Y or X.

Test 22d. For this test, relative displacements were monitored in the Y direction between the platen and the mirror mount, which is stiffly supported from the instrument bridge, on one transducer. The other transducer monitored the relative displacements between the same two locations, but in the Z direction. Both of the displacement components can contribute to image sweep in the Y direction, by "nodding" of the optical axis. For X-drive, a frequency search showed significant response only at 82Hz. Z-drive gave responses at 53 and 128 Hz, and Y-drive at 44 and 57 Hz. These were the frequencies used for the following recordings:

- 22-d-(1) Drive at the same location as for tests 22b, and 22c. Drive in X direction at 82 Hz. Record geophone response, and photograph scope 22-d-(1).

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

- 22-d-(2) Drive in Z direction at 53 Hz, scope photo 22-d-(2).
- 22-d-(3) Drive in Z direction at 128 Hz, scope photo 22-d-(3).
- 22-d-(4) Drive in Y direction at 44 Hz, scope photo 22-d-(4).
- 22-d-(5) Drive in Y direction at 57 Hz, scope photo 22-d-(5). Scope photo made after response geophone on bridge had been changed from vertical to horizontal Y.
- 22-d-(6). Drive in Y direction at 85 Hz, scope photo 22-d-(6).

Test 22e. In this test, impulses were made by hand on the side panel of the table supporting the instrument. Recordings were made of the signals from a Y-direction geophone and a Z-direction geophone located on top of the instrument bridge. Purpose was to measure response of the bridge to single-impulse type disturbances.

Record 22-e-(1) Impulse table side panel in the X-direction.

Record 22-e-(2) Impulse table rear panel in the Y-direction.

Test 22f. These tests were performed on 27 May 1971, to observe the responses of relative displacements, same as test 22d, while the following ambient noise environments were operating:

| <u>Source of Disturbance</u> | <u>Ref. Scope Photo</u> |
|--|-------------------------|
| Normal ambient room environment, quiet | 22-f-(1) |
| Same, but with teletype machine running | 22-f-(2) |
| Same, but with card keypunch machine running | 22-f-(3) |

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

Test Series 23-

Purpose: Record the ambient vibration disturbances for the purpose of power-spectral analysis, both on the floor, and at key points on the instrument. Make both velocity and displacement measurements, as appropriate.

Method: One standard EVS-8 vertical geophone was installed on the floor of the room, at the approximate center of the floor panel. Another vertical geophone was installed on the instrument platen. Relative displacement transducers were set up to measure the vertical displacement, Z_b , and the horizontal displacement, Y_b , of the objective lens barrel, relative to the instrument platen. These same transducers were also used to measure the displacements vertical, Z_c , and horizontal, X_c , of the eyepiece holder, relative to the instrument platen.

Measurements were made during normal ambient conditions, with no auxiliary equipment such as the teletype running, but with the instrument fan on, and the compressor of the adjacent X-Y plotter on and the plotter idle. Displacements were also measured due to light finger tapping on the table side panel to show audio-coupling effect on Z_b response, and with the impact of a man's heel's on the floor. It was observed that the natural frequency of the floor panel at this location is 25 Hz and with better than average damping, due probably to the heavy intermediate partitions employed in this area of the building.

Test 23a-1 Ambient disturbance, vertical velocity components at floor, \dot{Z}_A , and on instrument platen, \dot{Z}_p . Fan on. Plotter compressor on.

Test 23a-2 Same as 23a-1, but with X-Y plotter operating and plotting.

Test 23a-3 Relative displacement of objective lens, vertical Z_b , with floor velocity, \dot{Z}_A , under ambient vibration.

Test 23a-4 Same setup as 23a-3. Very light finger taps on the large sheet-metal side panel of the instrument table.

Test 23a-5 Relative displacement of objective lens, horizontal Y_b , with floor velocity, \dot{Z}_A , under ambient vibration.

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

Test 23a-6 With the same setup as 23a-3, impact of heels on floor, Z_b and \dot{Z}_A responses.

Test Series 24-

Purpose: Drive the floor at various frequencies, to amplitude of displacement levels equivalent to the predicted worst cases of the STAT Report. Measure and record the responses at the key points of the instrument.

Method: The instrumentation setup was the same as for the tests of Series 23-. The same notation is used. The DMI Vibration Driver was used at various locations on the floor, as appropriate, to produce the desired displacement amplitudes as measured by the vertical EVS-8 geophone, \dot{Z}_A , at the center of the floor panel, at each frequency of interest. The recordings of series 24a- were made with the instrument platen at about the center of its travel. The recordings of series 24b- were made with the platen moved to the forward edge of its travel. For the tests of series 24a, the displacements of the objective lens barrel, Y_b and Z_b , were recorded. For series 24b- the displacements measured are those of the eyepiece holder, X_c and Z_c . In both series, the vertical velocity component on the instrument platen was measured, and its records are noted \dot{Z}_p .

Test 24a-1 Sweep drive frequencies from 25Hz down to shut-off, monitor the velocity response of the instrument platen, \dot{Z}_p . Search for any resonant responses of significance, and check drive level.

Test 24a-2 Same as 24a-1, but record displacement Z_b of objective lens mount relative to platen.

Test 24a-3 Same as 24a-1, but record displacement Y_b .

Test 24a-4 Repeat 24a-1, record \dot{Z}_p , with a more correct drive level.

Test 24a-5 Drive floor at 18Hz, record Y_b .

Test 24a-6 Drive floor at 18Hz, record Z_b .

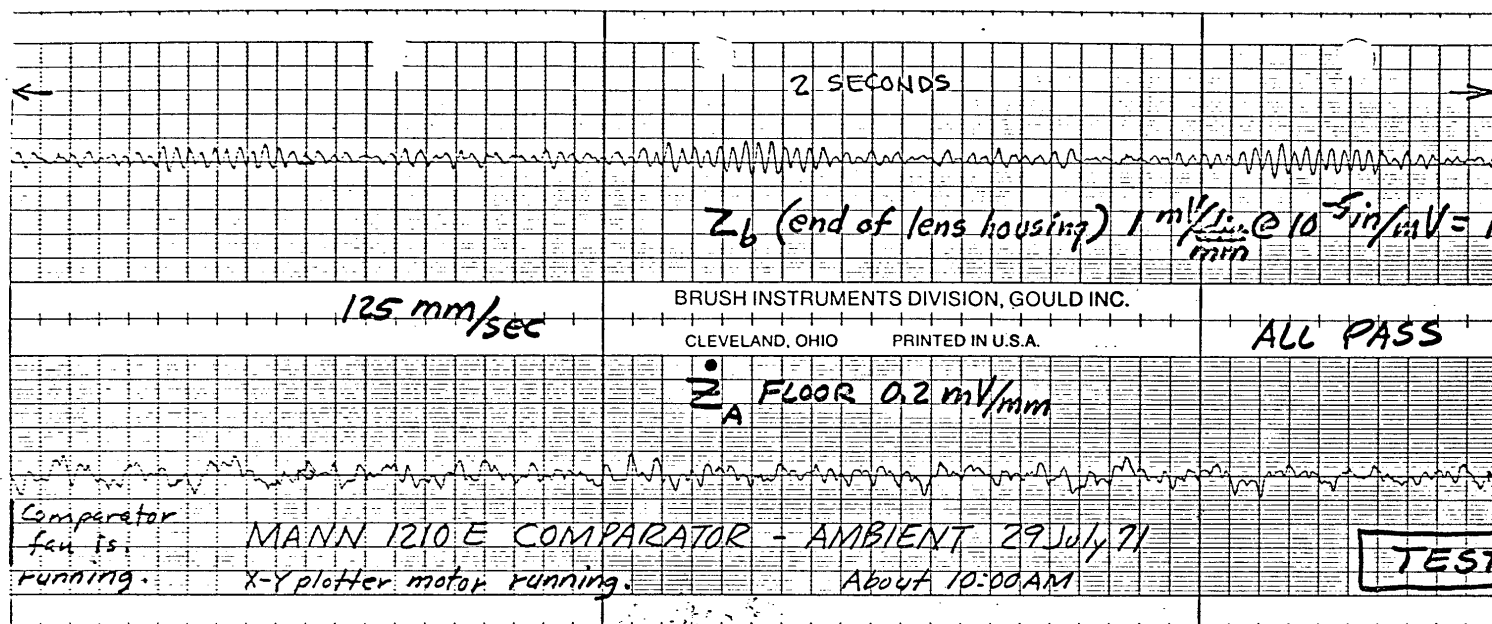
Test 24a-7 Drive floor at 18Hz, record \dot{Z}_p .

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4.2 Detail Description, Vibration Measurements - 1210E Mann Comparator (Contd.)

- Test 24a-8 Drive floor at 10Hz, record \dot{Z}_p .
- Test 24a-9 Drive floor at 10Hz, record Z_b .
- Test 24a-10 Drive floor at 10Hz, record Y_b .
- Test 24b-1 Make impact tests with fingers and hands on instrument, to simulate operator disturbances. Record Z_c response at eyepieces.
- Test 24b-2 Same as 24b-1, record X_c response.
- Test 24b-3 Drive at 10Hz, record Z_c response.
- Test 24b-4 Drive at 10Hz, record X_c response.
- Test 24b-5 Drive at 10Hz, record \dot{Z}_p response.
- Test 24b-6 Drive at 18Hz, record X_c response.
- Test 24b-7 Drive at 18Hz, record Z_c response.
- Test 24b-8 Drive at 18Hz, record \dot{Z}_p response.
- Test 24b-9 Drive at 25Hz, record \dot{Z}_p response.
- Test 24b-10 Drive at 25Hz, record Z_c response.
- Test 24b-11 Drive at 25Hz, record X_c response.

Figure 4.2.1 Test 23a-3



Test 23a-3

Mann 1210E Comparator Tests, 29 July 1971, 1000 Hrs.

Response of objective Lens Housing relative to platen surface under ambient floor vibration with fan in comparator base running and X - Y plotter compressor motor running. (Note: X - Y plotter occupies the same room as comparator.)

Displacement Transducer record of Z_b at point B of Figure 4.2.2.1Scale of Z_b , $1.0 \text{ mV/mm} = 1 \times 10^{-5}$ inches per chart mmGeophone record of Z_a at point A of Figure 4.2.2.1 (Center of floor panel)Scale of Z_a , $0.2 \text{ mV/mm} = 44 \times 10^{-5}$ inches per second per chart mm

Chart speed is 125mm/second or one major division equals 1/25 second

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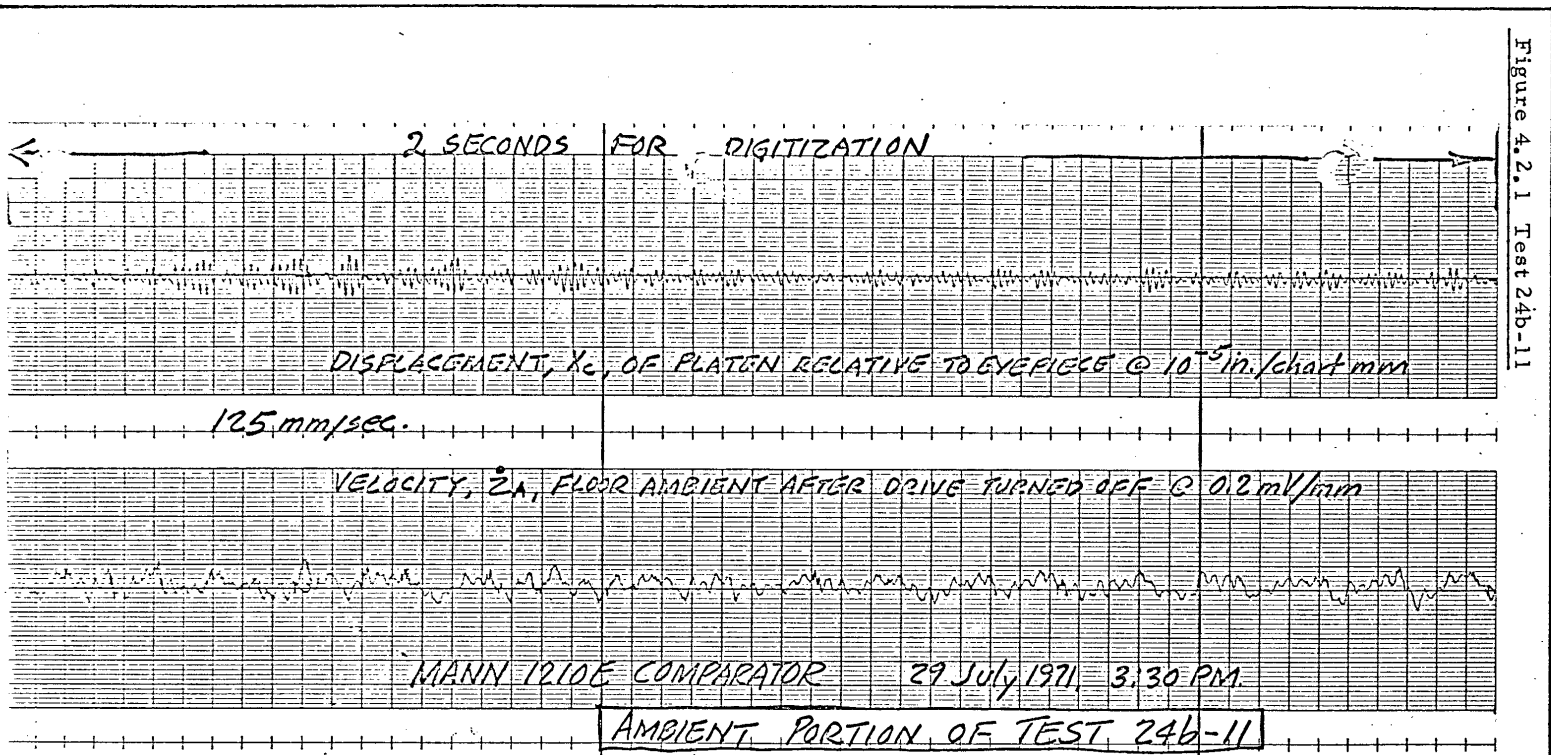


Figure 4.2.1 Test 24b-11

Test 24b - 11

Mann 1210E Comparator Tests, 29 July 1971, 1530 Hrs.

Response of eye piece holder relative to platen in X direction under ambient floor vibration with fan in comparator base running but X - Y plotter compressor motor OFF

Displacement Transducer record of X_c at point C of Figure 4.2.2.1

Scale of X_c , 1.0 mV/mm = 1×10^{-5} inches per chart mm

Geophone record of Z_a at point A of Figure 4.2.2.1 (Center of floor panel)

Scale of Z_a , 0.2 mV/mm = 44×10^{-5} inches per second per chart mm

Chart speed is 125mm/second, or one major division equals 1/25 second

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APPENDIX

Section 4.3

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4.3 Detail Description, Vibration Measurements - 1032T Mann Trichromatic Microdensitometer

Test series 31 through 33 were conducted on 26 through 28 May 1971. Test series 34 was made on 2 August 1971. For all tests, the instrument and its auxiliary equipment were in normal operating configuration, and the surrounding facilities in the building were in normal operation. Pertinent original data is reproduced in Appendix 4.3.1.

Test Series 31-

Purpose: Study the typical ambient disturbance environment for the machine in normal operation, and the responses at various points in the structural path of the machine, from its supports to the critical optical elements - light source, film platen and photo-sensors.

Method: Matched, calibrated geophones were used to monitor and record vibrations. One geophone remained on the floor as a continual monitor for floor ambient disturbances. The other geophone was placed at successive points of interest. For measurement of vertical vibration components (Z-axis, parallel to the optical axis), Type EVS-8, 4.5 Hz natural frequency geophones with 0.46 critical damping were used. For measurement of vibration components in the horizontal, X and Y axes, the pair of geophones were horizontally sensitive geophones with the same properties as the EVS-8's. The component of floor ambient vibration monitored was always the same as the component measured on the equipment. After preliminary checkout, the technique of sweeping frequency from 2.5 Hz to 200 Hz, using the 1/3-octave band pass filter of the GRC Analyzer, was used to produce a qualitative spectrum analysis of disturbances and responses. The tests of this series were as follows:

Note: The instrument drives are off, until further note.

Test 31-a. With both vertical geophones on the floor immediately in front of the instrument, record unfiltered ambient vertical (Z-axis) vibrations on one channel, and frequency sweep on the other channel. Air conditioning fans are on.

Test 31-b. Repeat Test 31-a, in the Y direction. Also make test record number 31-b-1, with the GRC on all pass. Air conditioning fans are on.

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4.3 Detail Description, Vibration Measurements - 1032T Mann Trichromatic Microdensitometer (Contd.)

Test 31-c. Repeat Test 31-a, in the X direction. Also make test record number 31-c-1, with the GRC on all pass. Air conditioning fans are on.

Test 31-d. Make a detailed spectral scan in the Z-axis, with both geophones on the floor in front of the instrument, to study the effect of the air conditioning fans on the level of disturbance in the floor.

Record 31-d-1 Fans on. Spectral scan 20 through 40 Hz, in 1 Hz steps.

Record 31-d-2 Fans off. Same, 20 through 40 Hz.

Record 31-d-3 Fans off. Spectral scan 2.5 Hz through 200 Hz in 5 Hz and 10 Hz steps (normal).

Record 31-d-4 Fans on. High-speed recording of ambient vibrations, no filtering.

Test 31-e. Spectral scan of Z components at foot of table, inside base structure on top of pad. Fans on. Includes a high-speed, unfiltered record.

Test 31-f. Same as 31-e., fans on, Z components at top of the microdensitometer base structure (structure that supports the instrument base casting). This is on top of the isolator mount. For this test, the microdensitometer's X-direction drive is still off.

Test 31-g. Same as 31-e., fans on, Z components at a location inside the optical head, a heavy cantilever structure. Instrument X-drive off.

Test 31-h. Same as 31-g., Instrument X-drive on. (First test with the instrument drive on.)

Test 31-i. Same as 31-g. Instrument drive off. Air-conditioning fans turned off.

Test 31-j. Same as 31-g. Instrument drive back on. Air fans still off.

Test 31-k. Spectral scan of Z components on instrument platen, plus an unfiltered high-speed record. Instrument drive off. Air fans off.

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4.3 Detail Description, Vibration Measurements - 1032T Mann Trichromatic Microdensitometer (Contd.)

Test 31-l. Same as 31-k, with instrument drive and air fans on.

Note: the above completed the Z-component measurements. The next series of records covered X-components of vibration.

Test 31-m. X-component spectral scan plus unfiltered high-speed record at the table foot, similar to 31-e. The floor monitor is also in the X-component direction. Fans and instrument X-drive are on.

Test 31-n. X-component at top of base structure, similar to 31-f. Fans and instrument drive are on.

Test 31-o. X-component at head, similar to 31-g. Fans and instrument drive are on.

Test 31-p. X-component at platen, similar to 31-k. Fans and instrument drive are on.

Test 31-q. Same as 31-p, but fans and instrument drive are off.

Test 31-r. Same as 31-p, fans off, instrument drive on.

Note: This completes X-component measurements.

Test 31-s. Y-component spectral scan plus unfiltered high-speed record at the table foot, similar to 31-e. The floor monitor is in the Y-component direction. Fans and instrument drive are on.

Test 31-t. Same as 31-s. Fans and instrument drive are off.

Test 31-u. Same as 31-s. Fans off, instrument drive on.

Test 31-v. Y-component at top of base structure, similar to 31-f. Fans and instrument drive are on.

Test 31-w. Same as 31-v. Fans and instrument drive are off.

Test 31-x. Y-component at optical head, similar to 31-g. Fans and instrument drive are off.

Test 31-y. Same as 31-x. Fans and instrument drive are on.

Test 31-z. Y-component at platen, similar to 31-k. Fans and instrument drive are on.

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4.3 Detail Description, Vibration Measurements - 1032T Mann Trichromatic Microdensitometer (Contd.)

Test 31-aa. Same as 31-z. Fans and instrument drive are off.

Note: The above completes the present series of ambient vibration tests. Special tests were next made with wooden wedges inserted adjacent to the spring isolator mounts, to determine the effect of ambient vibrations in the floor with the instrument hard-coupled to its base structure.

Test 31-ab. Y-component at platen. Fans on. Instrument drive off.

Test 31-ac. Same as 31-ab. Fans on. Instrument drive on.

Observation: Placing the wood wedges at the isolator mount pads apparently elastically warped the heavy instrument base structure sufficiently to distort the optical alignment. Distortion was equivalent to changing the density readout full scale. The (effective) slit dimension in use was 1 micron wide x 80 microns long. The probable equivalent dimensional distortion of the optical alignment was thus 2 microns, or about 80 microinches. This observation is of interest when considered in the light of the relative displacement measurements of Test Series 32, which follow:

Test Series 32-

Purpose: To study the relative movements of key components of the optical system under various disturbances.

Method: Relative displacement transducers were set up to measure displacement of the components of interest, relative to the instrument platen on which the supporting base for the transducers rested. For some tests, geophone records were also made to monitor the disturbances relative to inertial space.

Test 32-a-1 Transducers measure Z-component and Y-component of displacement of upper optical system barrel, relative to the instrument platen. Z-component is on Scope channel (1), Y-component on channel (2) "lower". A finger-tip impulse is produced in the X-direction on the side of the optical head. The reaction and die-out relative to the platen is photographed on the scope (scope photo 32-a-1). Scope sweep is 20 ms/cm. Amplitudes are (1) 50 mV/cm, and (2) 10mV/cm. Air conditioning fans are off.

Observation: Response is at 82 Hz. Damping is computed to be approximately 22.5% of critical.

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4.3 Detail Description, Vibration Measurements - 1032T Mann Trichromatic Microdensitometer (Contd.)

Test 32-a-2 The test of 32-a-1 was repeated, with an improved transducer clamping arrangement, to assure pure relative motion measurements as far as possible.

Observation: Response is now at 93 Hz, and damping is computed to be approximately 20% of critical. Displacement caused was about 12 microns, or 475 microinches.

Test 32-a-3 The set-up was changed to measure Z-component and X-component of displacement, rather than Y. Test procedure of 32-a-1 was again repeated and recorded on scope photo 32-a-3.

Test 32-a-4 A horizontal geophone is placed on the platen to monitor X-component of vibration. Air conditioning fans are turned on. Relative displacements in the X direction are measured between the head optics and the platen and displayed on channel (2) of the scope. The geophone output is displayed on channel (1). Scope photo 32-a-4a has too slow a sweep rate. Scope photo 32-a-4b has sweep rate of 10 milliseconds/cm. Channel (1) amplitude is 0.5 mV/cm. Channel (2) amplitude is 1.0 mV/cm.

Test 32-a-5 A recheck was then made of the X-components of ambient disturbances, unfiltered on the floor, and with a spectral scan at the platen. This record is on Brush recorder chart 32-a-5. The air conditioning fans are on.

Test 32-a-6 Test 32-a-5 was repeated with the air conditioning fans off.

Note: This concluded the tests of series 32.

Test Series 33-

Purpose: To obtain a correlation between vibration disturbances reaching the instrument platen, and the density readout on the control panel recorder. When vibration sources, such as worn fan belts, generate disturbances in the 30 Hz range, these can be amplified by the approximately 30-Hz mounting of the isolators. When the upper aperture is being used as the limiting source of light, relative motion between the film platen and the optical axis of the source can produce degraded or erroneous data collection if displacements are high enough.

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4.3 Detail Description, Vibration Measurements - 1032 T Mann Trichromatic Microdensitometer (Contd.)

Method: The microdensitometer operator set up a sharp edge image on the scanner. The optical system was zeroed, to produce a sharp rise in the density record as the scanning spot crossed the image edge. Transducers were set up to monitor relative displacement in the X direction between head optics and platen, and to monitor horizontal velocity in the X direction, using horizontal geophone, on the platen. These set-ups were made as Steps 33-a and 33-b.

Test 33-c. With ambient vibrations from air conditioning fans on, fingertip impulses were made on the side of the optical head, as in Test 32-a-1. Records were made on scope photography, and are numbered 33-c-1 through 33-c-3. These correspond with density recordings of the same numbers.

Test 33-d. For this test, chart scale vertical deflection was 1 inch on chart represents a change in transmission of 10%. The impact is recorded on scope photo 33-d-1, and the chart is numbered 33-d-1.

Test 33-e. This was an impulse reaction test, using a relative displacement transducer between the instrument base casting and the supporting table, across the isolator mount. The transducer measured displacement in the Z direction. Scope photo 33-e-1 shows the displacement due to impulse. Scope photo 33-e-2 includes the record from an X-component horizontal geophone in the optical head.

Test 33-f. This test was the same as 33-e, except that the relative displacement transducer measured displacements in the X direction. The geophone record is again of velocity components in the optical head, in the X direction.

Test Series 34-

Purpose: Measure and record the responses of the microdensitometer to ambient floor disturbances, heel impulses, and sinusoidal excitation of the floor panel at worst-case levels, at frequencies of 10, 18, and 25 Hz.

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4.3 Detail Description, Vibration Measurements - 1032T Mann Trichromatic Microdensitometer (Contd.)

Method: Responses of the instrument were measured by means of EVS-8 vertical geophones at the instrument platen, and on the instrument base casting. Response of the floor was monitored by an EVS-8 vertical geophone at the center of the floor panel and was used to set the sinusoidal drive levels. The floor was driven, for the sinusoidal cases, by the DMI Vibration Driver, adjusted and located for each test to produce the desired amplitude level of floor response.

The response of the microdensitometer was also recorded by making use of the instrument's own density plot, from the recorder on the control panel. Density readings were produced by scanning across the edge of a bar target of known edge sharpness, as follows:

| | |
|---|---------------------|
| Scan rate, X-direction | 0.125mm per minute |
| Recorder chart speed | 6 inches per minute |
| Effective scanning aperture | 80 microns |
| (actual aperture of 1 micron, with 80X magnification) | |
| Chart full scale value | Density 2.5 |

In each density readout test, the density record was first produced by scanning under normal ambient conditions, then the record was repeated by scanning during sinusoidal excitation of the floor to the predicted worst-case levels. This record can thus be compared with the control record to see any loss of resolution produced by the higher vibration levels.

Test 34a-1. Impulse from heel, record response vertical velocity component on floor, \dot{Z}_A , and on instrument base casting, \dot{Z}_B .

Test 34a-2.

Test 34a-3. Same as 34a-1, record \dot{Z}_A , and on platen, \dot{Z}_C .

Test 34b-1. Ambient vibration, record \dot{Z}_A and \dot{Z}_C .

Test 34b-2. Ambient vibration, record \dot{Z}_A and platen horizontal velocity component, \dot{X}_C .

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4.3 Detail Description, Vibration Measurements - 1032T Mann Trichromatic Microdensitometer (Contd.)

Test 34b-3. Same as 34b-1.

Test 34c-1. Determine proper locations for driver to simulate predicted

Test 34c-2. [] worst case. Drive at 12Hz and 25Hz, record \dot{Z}_A and \dot{Z}_C and STAT

Test 34c-3. X_C , drive at 25Hz, record \dot{Z}_A and \dot{Z}_C .

Test 34d-1. Drive floor at 25Hz, at predicted worst-case level. Record \dot{Z}_A and \dot{X}_C , while making density readout on instrument, as explained under "Method" above. Immediately prior to the driving of the floor, make a control density readout under normal quiet ambient conditions.

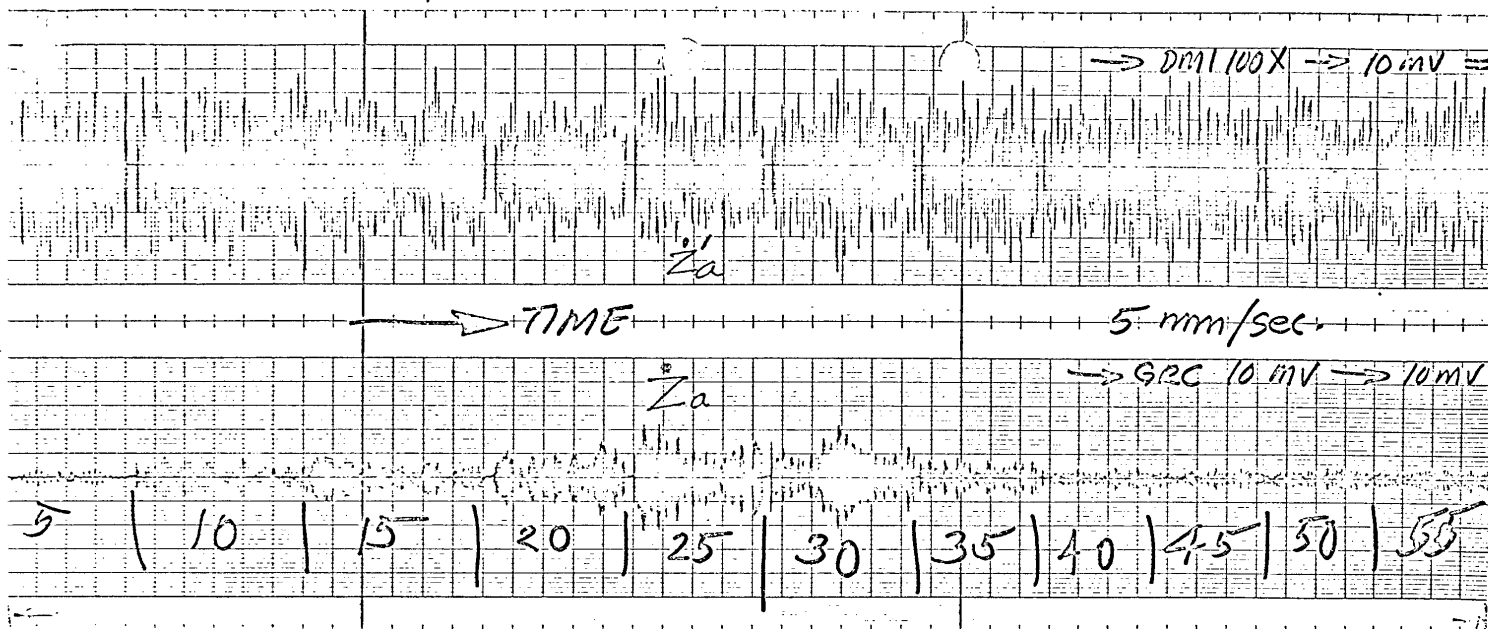
Test 34e-1. Drive floor at 10Hz, record \dot{Z}_A and \dot{Z}_C .

Test 34e-2. Drive at 10Hz, make density readout before and during drive, record \dot{Z}_A and \dot{X}_C .

Test 34f-1. Drive at 18Hz, make density readout before and during drive, record \dot{Z}_A and \dot{X}_C .

Test 34f-2. Drive at 18Hz, record \dot{Z}_A and \dot{Z}_C .

Figure 4.3.1 Test 31-a

Test 31-a

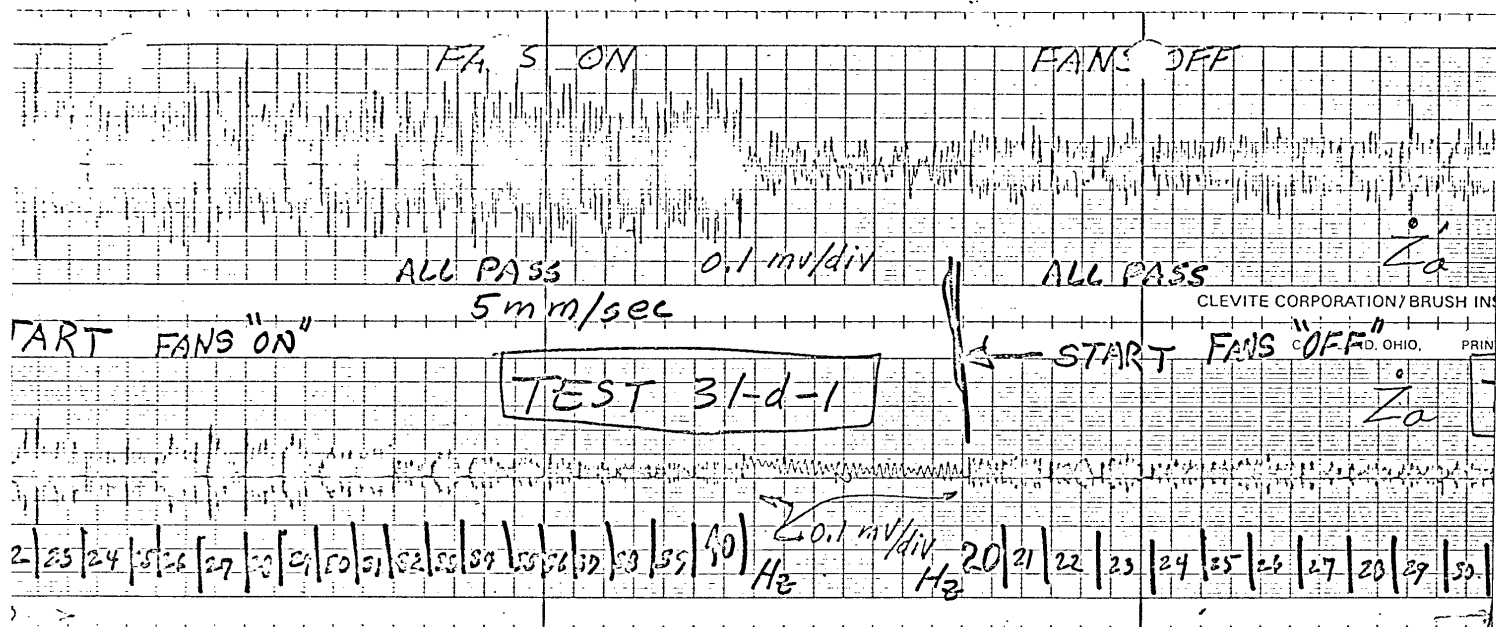
Mann 1032T Trichromatic Microdensitometer, 26 May 1971, 1350 hrs. Record of floor ambient vibration (vertical) at point A upper record "all pass" and lower record a spectral sweep through the GRC 1/3 octave filter in 5 Hz increments. Clean room fans ON.

Geophone record \dot{Z}_a , all pass, 0.1 mv/mm = 22×10^{-5} inches per second per chart mm.

Geophone record \dot{Z}_a , thru GRC filter, 0.1 mv/mm = 22×10^{-5} inches per second per chart mm. Chart speed 5 mm per second.

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Test 31d-1 and Test 31d-2 Mann 1032T Trichromatic Microdensitometer, 26 May 1971, 1320 hrs.

Comparison of floor vibration (vertical) at point A in front of instrument with clean room fans ON vs. OFF. Geophone \dot{Z}_a scale 0.1 mv/mm = 22×10^{-5} inches per second per chart mm. All pass geophone record. Geophone \dot{Z}_a spectral sweep through GRC 1/3 octave filter. Scale 0.1 mv/mm = 22×10^{-5} inches per second per chart mm. Chart speed 5 mm/second.

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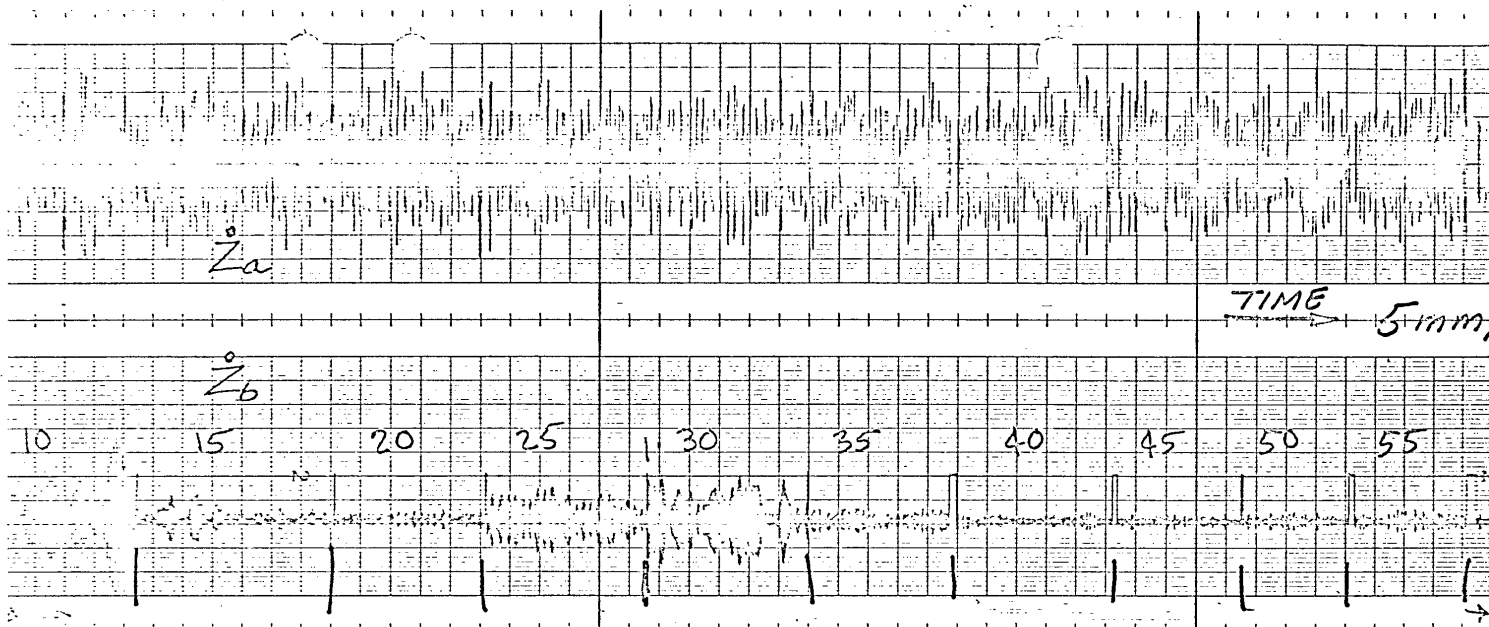
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Figure 4.3.1 Test 31-e

Test 31-e

Mann 1032T Trichromatic Microdensitometer, 26 May 1971, 1420 hrs. Comparison of floor ambient vibration (vertical). Fans ON at point A with response on top of isolator pad at point B. Geophone record \dot{Z}_a , "all pass", $0.1 \text{ mv/mm} = 22 \times 10^{-5}$ inches per second per chart mm. Geophone record \dot{Z}_b , spectral sweep through GRC 1/3 octave filter, 5 Hz increments. Scale $0.1 \text{ mv/mm} = 22 \times 10^{-5}$ inches per second per chart mm. Chart speed 5 mm per second. Resonant response of pads at 10 Hz shows by comparing to Test 31-a.

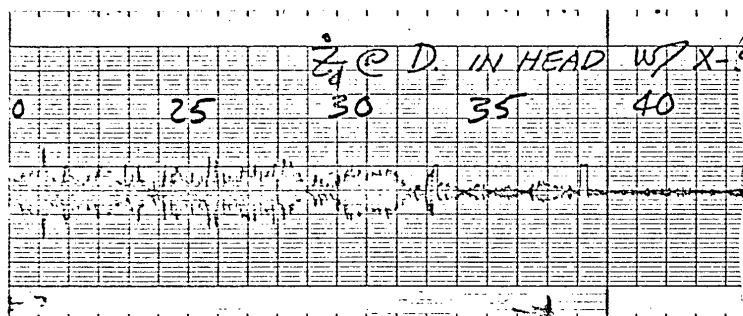
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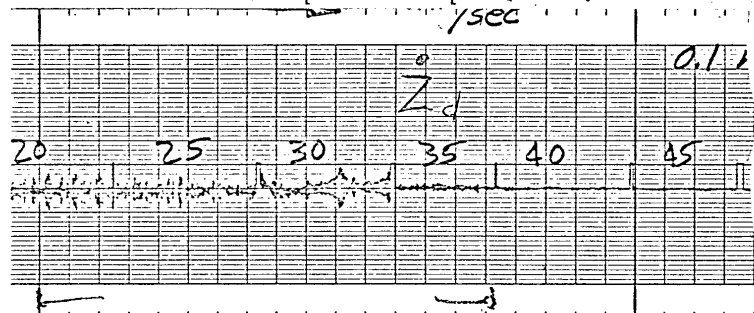
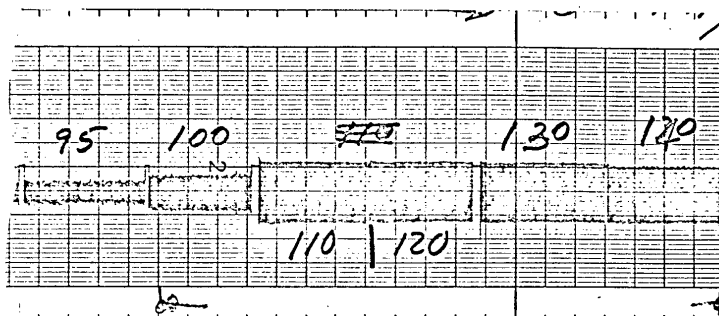
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Test 31-h

Mann Trichromatic Microdensitometer, 26 May 1971, 1500 hrs. Spectral sweep of vertical vibration at head of instrument, point D with fans ON and X drive of instrument ON. Section 20 to 40 Hz and 95 to 140 Hz shown. Geophone \dot{Z}_d , 0.1 mv/mm = 22×10^{-5} inches per second per chart mm. Chart speed 5 mm per second.



Test 31-i

Mann Trichromatic Microdensitometer, 26 May 1971, 1510 hrs. Spectral sweep of vertical vibration at head of instrument, point D with Fans OFF and X drive of instrument OFF for comparison to Test 31-h. Section 20 to 45 Hz and 95 to 140 Hz shown. Geophone \dot{Z}_d , 0.1 mv/mm = 22×10^{-5} inches per second per chart mm. Chart speed 5 mm/second.

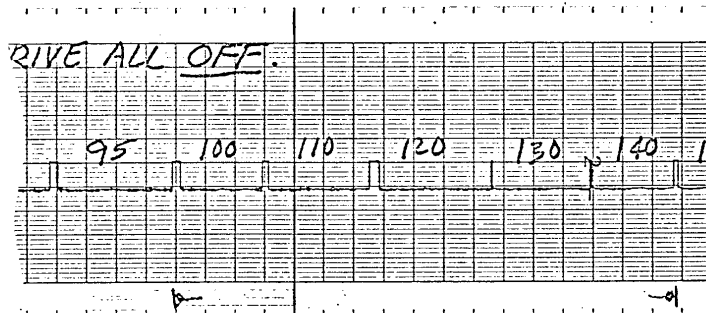
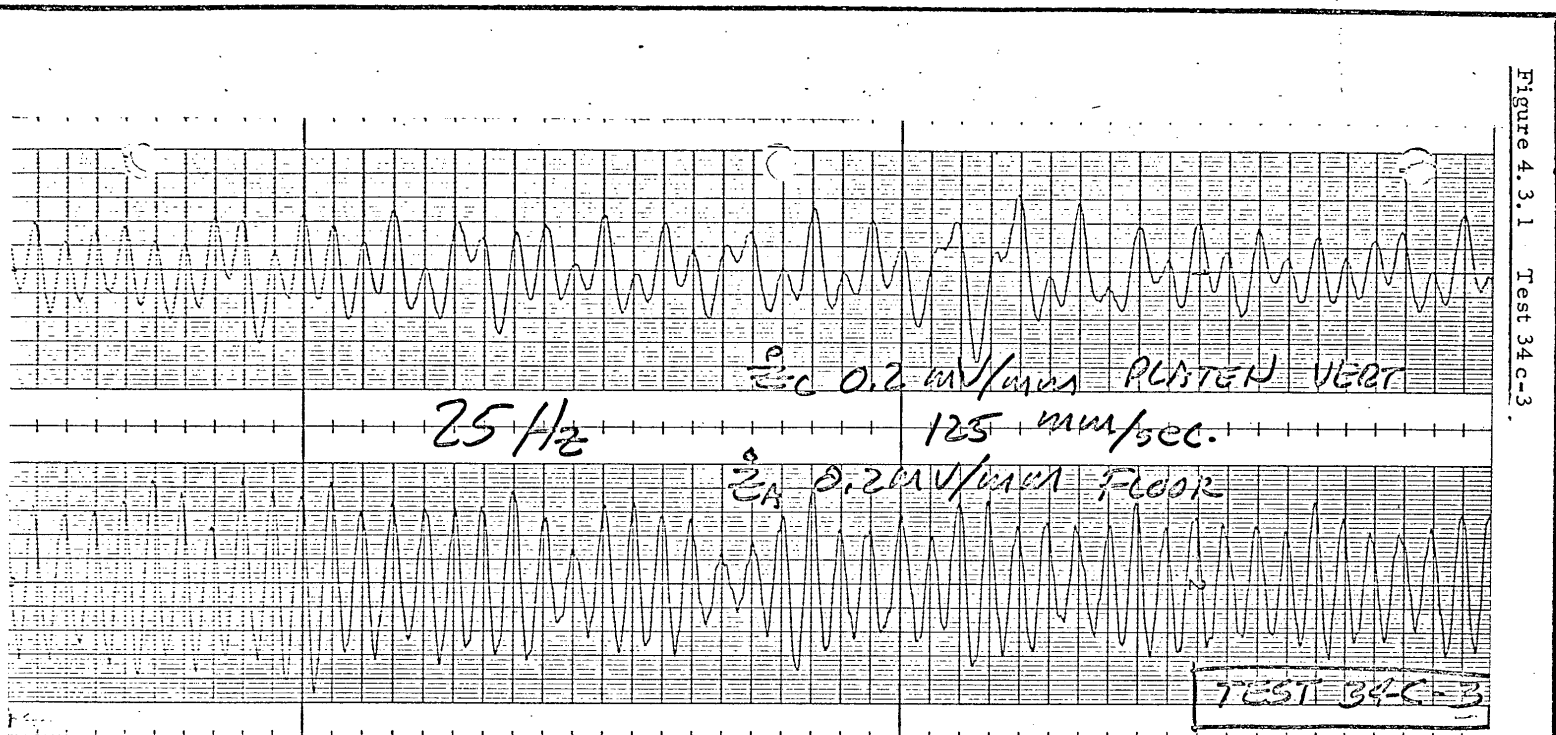
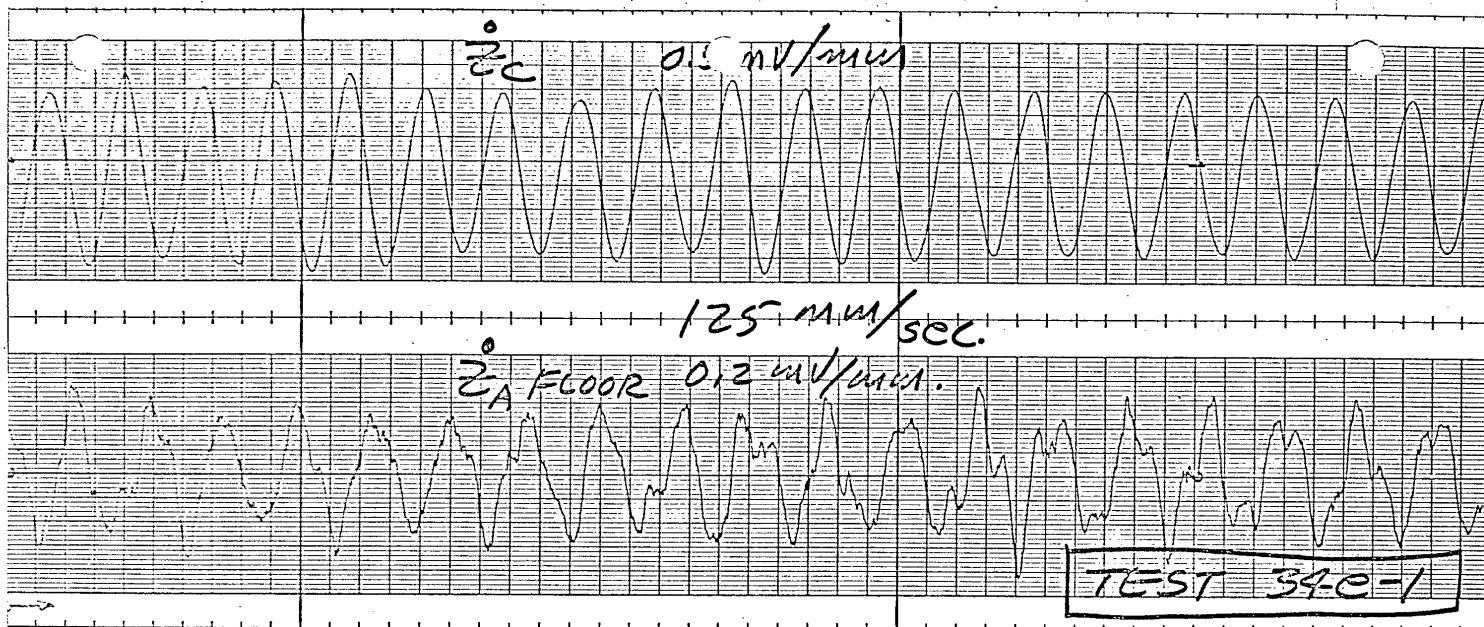


Figure 4.3.1 Test 31-h and 31-i



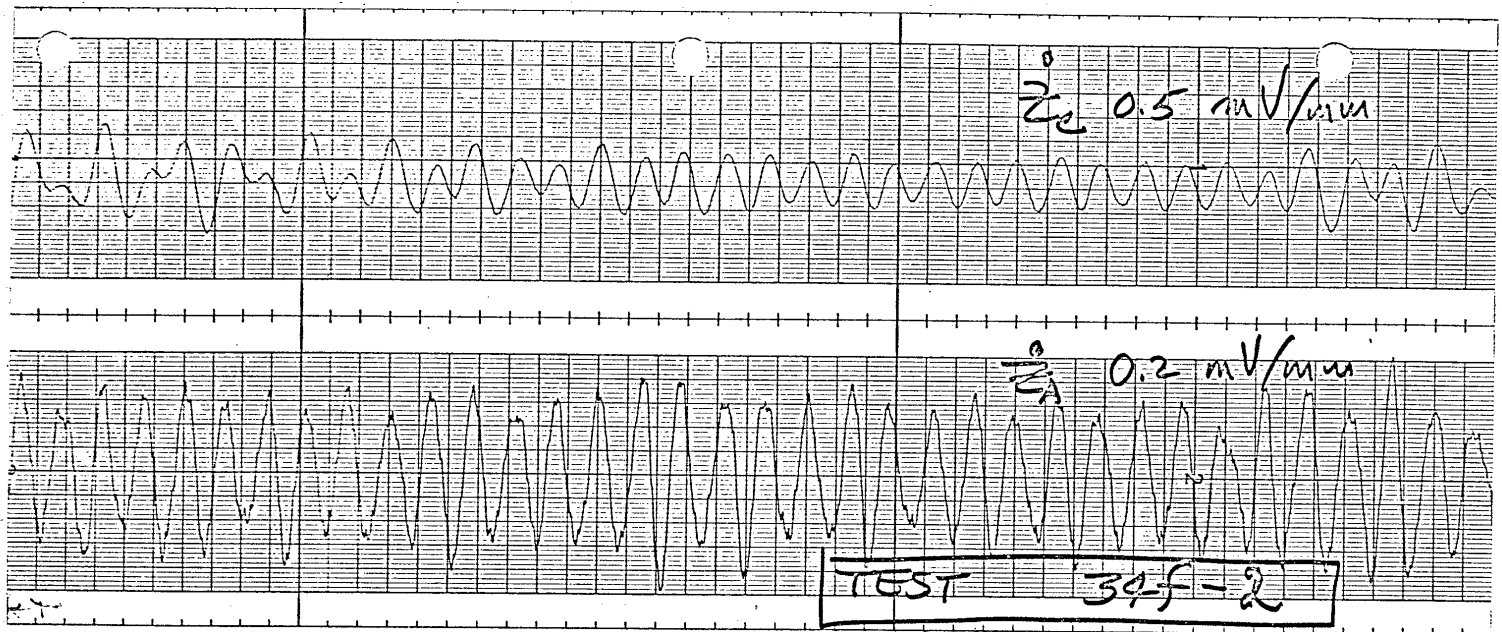
Test 34c-3 Mann 1032T Trichromatic Microdensitometer, 2 August 1971, 1330 hrs. Response of platen (vertical vibration) measured at point C to 25 Hz floor drive at "worst case" level measured at point A. All records full wave. Geophone record, \dot{Z}_C , platen, 0.2 mv/mm = 44×10^{-5} inches per second per chart mm. Geophone record, \dot{Z}_A , floor (vertical), 0.2 mv/mm = 44×10^{-5} inches per second per chart mm. Chart speed 125 mm/second.

Figure 4.3.1 Test 34e-1



Test 34e-1 Mann 1032T Trichromatic Microdensitometer, 2 August 1971, 1320 hrs.. Response of platen (vertical vibration) measured at point C to 10 Hz floor drive at "worst case" level measured at point A. All records full wave. Geophone record \dot{Z}_C , 0.5 mv/mm = 11×10^{-4} inches per second per chart mm. Geophone record \dot{Z}_A , 0.2 mv/mm = 44×10^{-5} inches per second per chart mm. Chart speed 125 mm/second.

Figure 4.3.1 Test 34f-2



Test 34f-2 Mann 1032T Trichromatic Microdensitometer, 2 August 1971, 1350 hrs. Response of platen (vertical vibration), measured at point C, to 18 Hz floor drive at "worst case" level measured at point A. Geophone record Z_C , 0.5 mV/mm = 11×10^{-4} inches per second per chart mm. Geophone record Z_A , 0.2 mV/mm = 44×10^{-5} inches per second per chart mm. Chart speed 125 mm/second.

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4.4 Detail Description, Vibration Tests - Kodak Beacon Enlarger

Five series of tests (Test Series 41 through 45) were made on 28 May, 1 June and 2 June 1971. These tests, their purposes and the data obtained are described below in chronological order. Pertinent original data is reproduced in Appendix 4.4.1.

Test Series 41 -

Purpose: Monitor and record the ambient vibrations on slab floor and along load paths of the Beacon Enlarger, S/N 001.

Method: Note that the optical axis (Z) is horizontal on the Beacon Enlarger with X axis being transverse and horizontal and Y axis being vertical. A series of spectrograms of the ambient vibrations (Y) first on the floor and then on various parts of the equipment were recorded utilizing vertical EVS-8A geophones for Tests 41-a through 41-b. The blower supplying vacuum to the easel was turned off or on for particular tests. Concurrently with the spectrograms, floor ambient (Y) recordings were also made on the other channel of the Brush Recorder. A similar series of tests (41-f through 41-k) were made with the EVS-8AH horizontal geophones recording X simultaneously on the device and the floor. Tests 41-l through 41-q were made similarly with horizontal geophones except Z was recorded on the device and on the floor.

Test 41-a All geophones Y direction (vertical). Vibration was recorded on floor (Y). Spectral sweep of Y floor vibration with GRC on 1/3 octave filter. Tests begun on 28 May 1971 at 1315. Blower on.

Test 41-b Repeat 41-a except spectral sweep geophone on nearside isolation mount at position 2. Blower on. Velocity recorded (Y).

Test 41-c Repeat 41-b except blower off.

Test 41-d Repeat 41-a except spectral sweep geophone on lens mount. Blower off.

Test 41-e Repeat 41-d except blower on.

Test 41-f All geophones X direction (horizontal). Vibration was recorded on floor (X). Spectral sweep of X floor vibration with GRC on 1/3 octave filter. Blower on.

Test 41-g Repeat 41-f except blower off.

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4.4 Detail Description, Vibration Tests - Kodak Beacon Enlarger (cont'd)

Test 41-h Repeat 41-f except spectral sweep geophone on isolation mount at position 2. Blower on.

Test 41-i Repeat 41-h except blower off.

Test 41-j Repeat 41-f except spectral sweep geophone on lens mount. Blower off.

Test 41-k Repeat 41-j except blower on.

Test 41-l All geophones in Z direction (horizontal). Vibration was recorded on floor (Z). Spectral sweep of Z floor vibration with GRC on 1/3 octave filter. Blower on.

Test 41-m Repeat 41-l except blower off.

Test 41-n Repeat 41-l except spectral sweep geophone on mount at position 2. Blower off.

Test 41-o Repeat 41-n except blower on.

Test 41-p Repeat 41-l except spectral sweep geophone on lens mount. Blower on.

Test 41-q Repeat 41-p except blower off.

Note low frequency modulation (1.6 Hz) in Z records of horizontal geophone may have been caused by loose weight on geophone discovered at end of series.

Test Series 42 -

Purpose: Monitor vibrations at center of vacuum easel (on optical axis) with lens to platen distance 61" (typical).

Method: Use the easel vacuum to hold the geophone to the easel center approximately on the optical axis. A 13" x 33" x .060" thick aluminum sheet is vacuum held to the platen. The Z geophone is cemented to the sheet. The X and Y geophones are cemented to a 1-1/2" x 1-1/2" x 3" aluminum block which in turn is cemented to the large sheet. The blower was on for these tests. The tests were conducted on 1 June 1971.

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4.4 Detail Description, Vibration Tests - Kodak Beacon Enlarger (cont'd)

Test 42-a All geophones in \dot{Y} direction (vertical). Vibration was recorded on floor (\dot{Y}). Spectral sweep of \dot{Y} easel vibration with GRC on 1/3 octave filter.

Test 42-b Repeat 42-a except all geophones in Z direction (horizontal) and \dot{Z} was recorded on floor with a spectral sweep of \dot{Z} vibration on the easel.

Test 42-c Repeat 42-a except all geophones in X direction (horizontal) and \dot{X} was recorded on floor with a spectral sweep of \dot{X} vibration on the easel.

Test Series 43-

Purpose: Investigate spring rate of isolator mounts at easel end of Beacon

Method: A dial gauge was installed across isolator to measure deflection of isolator under additional load. Record no load and loaded readings of dial gauge. The tests were conducted on 2 June 1971.

Test 43-a No load reading (existing static load) dial gauge - 0.011". Added load of 200 lbs. symmetrically on two isolators, dial gauge - 0.064". Deflection = 0.053" for 100 lbs. and spring constant is 1900 lb./in.

Test 43-b Repeat 43-a. Deflection was 0.047" for 100 lbs. Spring constant is 2,130 lb./in. Average of both tests is $K = 2000$ lb./in.

Test Series 44-

Purpose: Determine resonant frequency of main suspension and damping by impulse reaction measurements.

Method: Install displacement transducers DMI P/N 30615-1 across isolator mounts A and B per Figure 4.4.2.1. Heel impact the floor midway between A and B. Record the response by oscilloscope photo with channel (1) on A position transducer - channel (2) on B position transducer. The tests were conducted on 2 June 1971.

Test 44-a Record scope photos of response to floor impact of transducers at A and B isolators. Sweep = 100 milsec/cm. Sensitivity = 20 milvolts/cm.

Test 44-b Record scope photos of response to floor impact of transducers at A & B isolators. Sweep = 100 milsec/cm. Sensitivity = 50 milvolts/cm.

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4.4 Detail Description, Vibration Test - Kodak Beacon Enlarger (cont'd)

Test Series 45-

Purpose: Study the Beacon Enlarger response to the 10 Hz ambient noise predicted and to the resonant frequency of the isolation mounts.

Method: Use Mechanical Floor Driver, DMI P/N 30619, and drive floor at 10 Hz on floor at central position between mounts. Record X, Y and Z direction responses on floor and on device. Record displacement across isolator mounts (Y). Blowers on for all records.

Test 45-a All geophones in Y direction. Record \dot{Y} at lens mount position D through GRC 1/3 octave filter set at 10 Hz. Record full wave \dot{Y} on floor at C. Drive floor with driver at 10 Hz and also make record of ambient background without drive.

Test 45-b Repeat 45-a except record lens \dot{Y} response full wave and floor \dot{Y} response through GRC 1/3 octave filter at 10 Hz. Drive floor at 10 Hz.

Test 45-c Repeat 45-a except record \dot{Y} full wave both on lens mount and floor and sweep floor drive frequency slowly from 0 to impact frequency of driver (13 Hz to 14 Hz with this weight setting). Note any resonant responses.

Test 45-d Repeat 45-a and record \dot{Y} as before. Also record oscilloscope photos of transducer deflection across mounts at A and B under 10 Hz floor drive.

Test 45-e All geophones in Z direction. Blower on. Record \dot{Z} full wave on floor and lens mount at C and D. Ambient vibration only without floor drive. Check for previously found low frequency modulation per test 41-1. (none discovered).

Test 45-f All geophones in Z direction. Drive floor at 10 Hz. Record full wave \dot{Z} on floor at C. Record \dot{Z} through GRC 1/3 octave filter set at 10 Hz on lens mount.

Test 45-g Repeat 45-f except no drive with both geophones recording \dot{Z} . The floor geophone records full wave and the geophone on the lens records a spectral sweep through the GRC 1/3 octave filter. Also record full wave ambient for both. All blowers on.

Test 45-h All geophone record in X direction. Drive the floor in Y direction at 10 Hz. Record floor response full wave \dot{X} . Record lens mount \dot{X} response through the GRC 1/3 octave filter set at 10 Hz.

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Figure 4.4.1 Test 43 - Beacon Enlarger Investigation

1. Purpose of Test

Check spring rate of mount at easel end of unit.

2. Procedure

Test conducted on 2 June 1971. Check deflection of mount under 100 lb. increase in static load. Calculate spring rate.

3. Data

Trial a - Set up dial gage across mount.

No load reads 0.011

Load reads 0.064 loaded W/WCM 200# Sym about
CL or 100# per mount.

$$K = \frac{100\#}{.064 - .011} = \frac{100}{.053} = 1.9 \times 10^3 = 1900 \text{ lb/in.}$$

Trial b - Repeat

Loaded .060

Unloaded .013

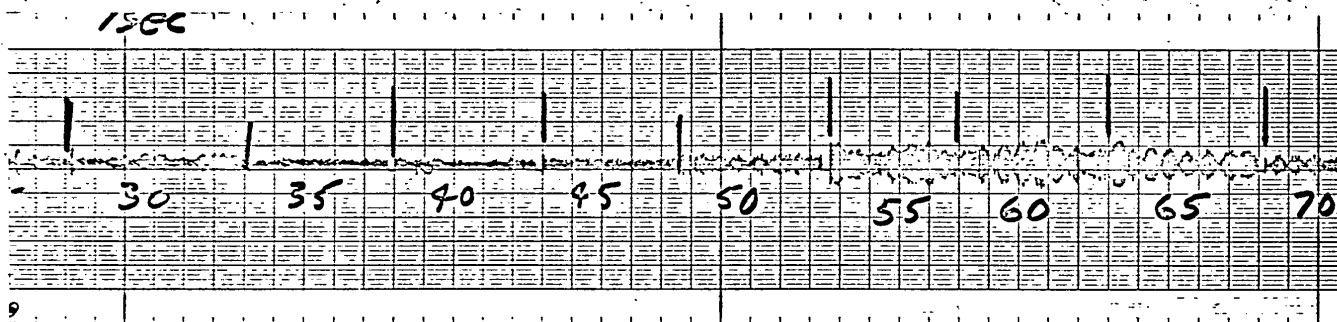
Net = .047

$$K = \frac{100}{.047} = 2,130 \text{ lb/in.}$$

4. Conclusions

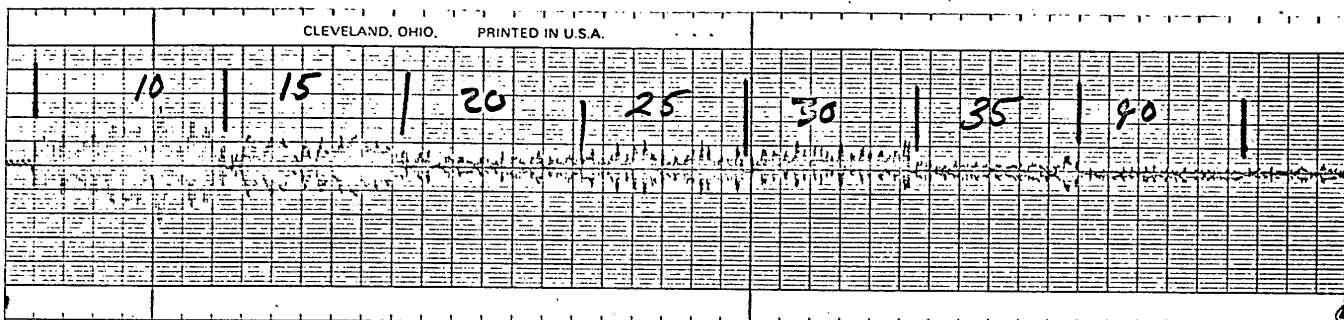
Average = 2,000 lb/in. which seems the probable spring rate of the rubber mount. This is assumed to be typical of all four mounts.

Figure 4.4.1 Test 41-a

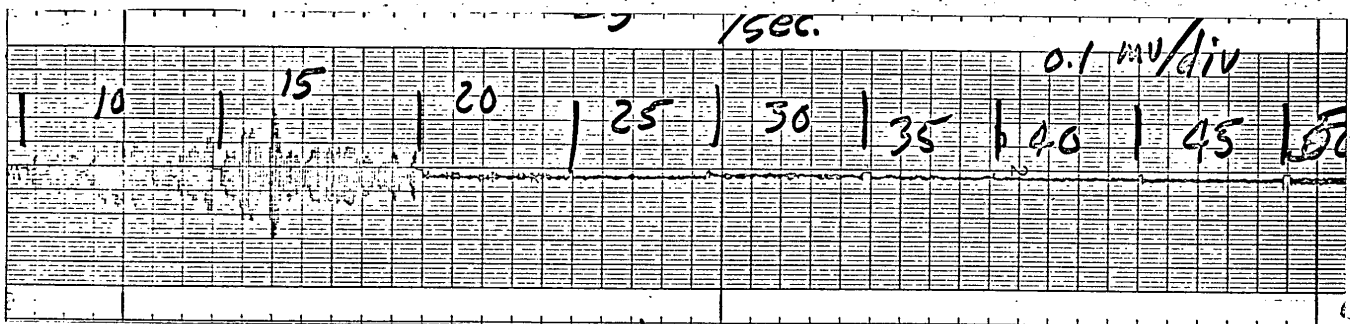


Test 41-a

Beacon Enlarger Test, 28 May 1971, 1315 hrs. Spectral sweep of Y (vertical) floor vibration, Blower ON. Spectrum taken in 5 Hz increments with a 1/3 octave GRC filter. Geophone record of floor ambient \dot{Y}_c at point c of figure 4.4.2.1 or report. Scale 0.1 mv/mm = 22×10^{-5} inches per second per chart mm.
Note: 60 Hz is dominant in floor with blower ON.



Test 41-b Beacon Enlarger Test, 28 May 1971, 1320 hrs. Spectral sweep of Y (vertical) of response at isolator #2 to floor ambient, Blower ON. 5 Hz intervals with 1/3 octave GRC filter. Geophone record of Y_2 at point 2, scale 0.1 mv/mm = 22×10^{-5} inches per second per chart mm. Note: 10, 15, 25, 30 Hz are dominant.



Test 41-c Beacon Enlarger Test, 28 May 1971, 1340 hrs. Spectral sweep of Y (vertical) of response at isolator #2 to floor ambient. Blower Off, 5 Hz increments with 1/3 octave GRC filter. Geophone record of Y_2 at point 2. Scale 0.1 mv/mm = 22×10^{-5} inches per second. Note: With blower OFF the disturbance above 15 Hz is essentially gone on board the Beacon Enlarger.

Figure 4.4.1 Test 41-b and 41-c

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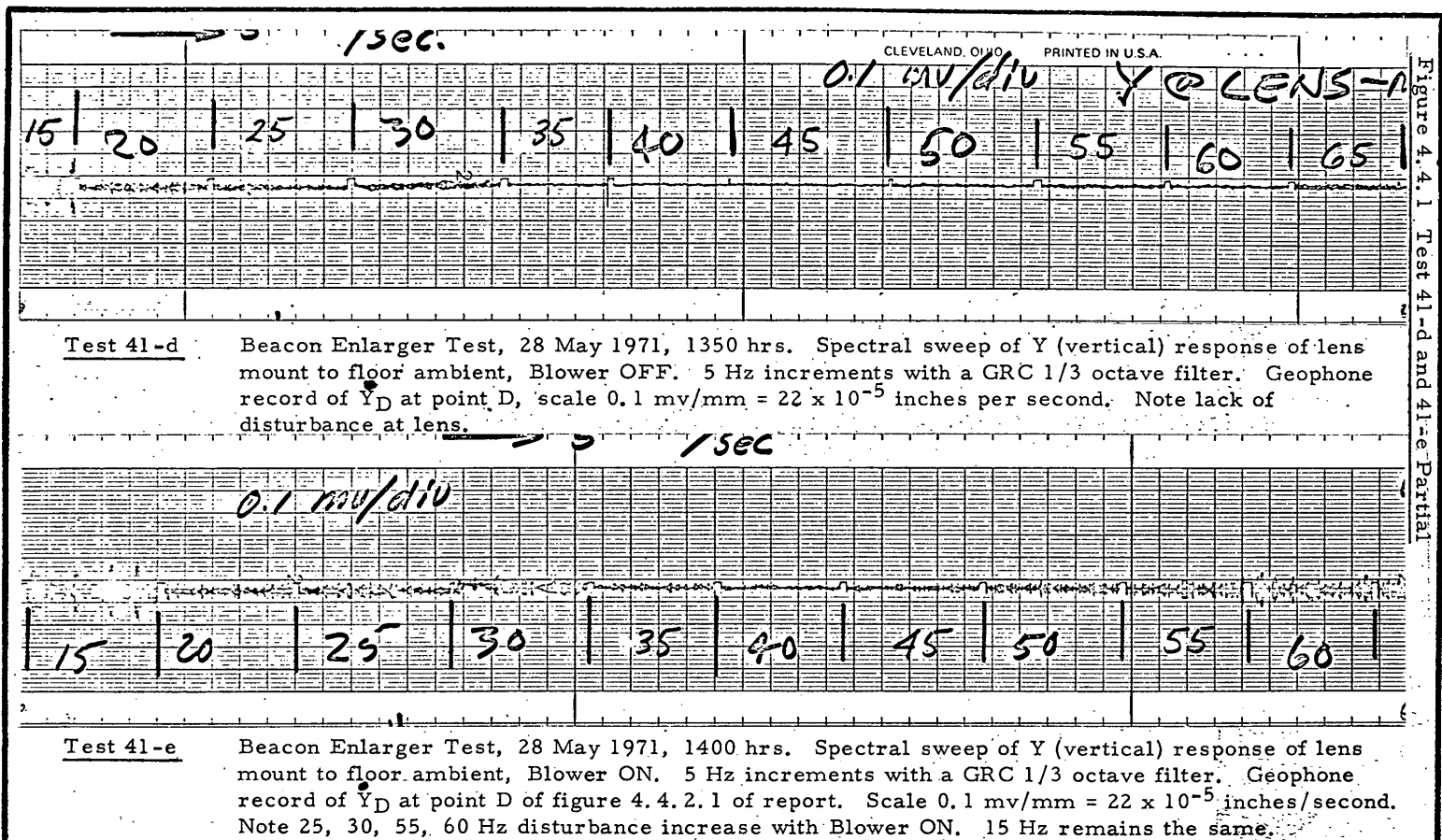


Figure 4.4.1 Test 41-d and 41-e-Partial

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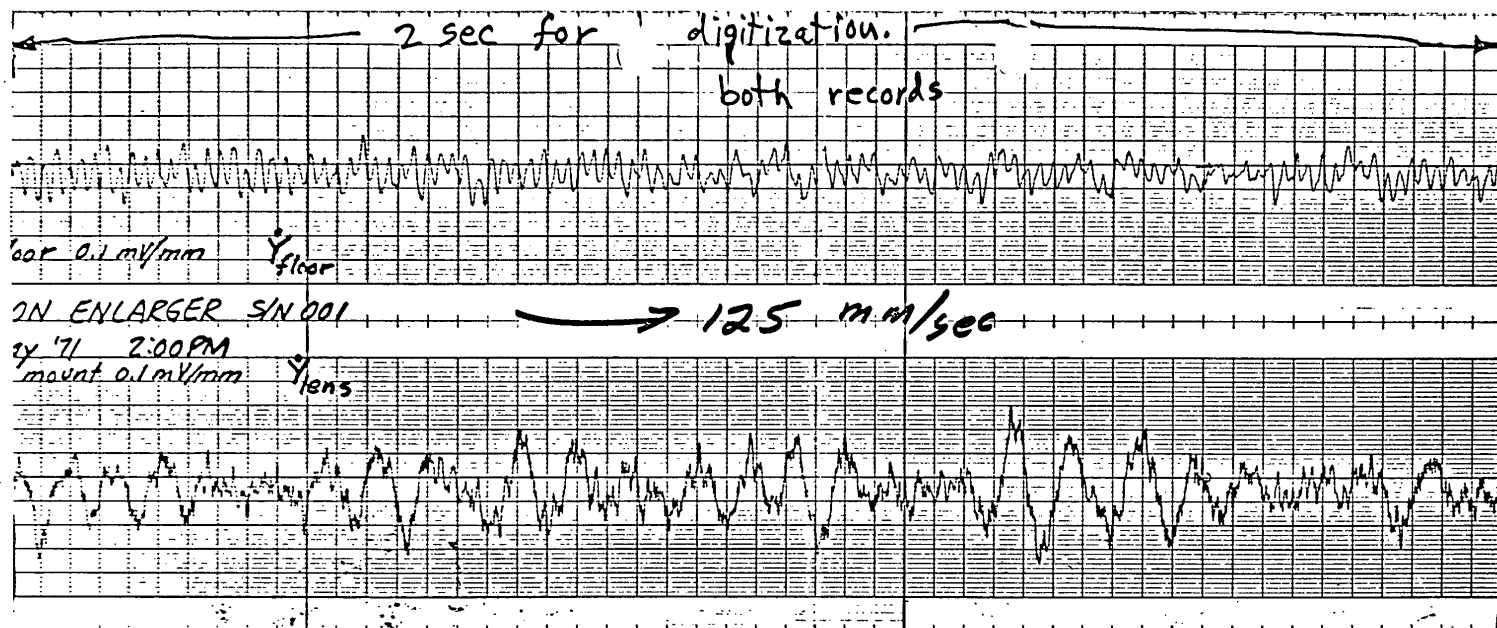


Figure 4.4.1 Test 41-e

Test 41-e

Beacon Enlarger Tests, 28 May 1971, 1400 Hrs.

Response of Lens Mount in Y (vertical) direction to floor ambient vertical vibration,
Blower ON

Geophone record of floor ambient, \dot{Y}_C , at point C of Figure 4.4.2.1 of Report

Scale 0.1 mV/mm = 22×10^{-5} inches per second per chart mm

Geophone record of Lens Vibration, \dot{Y}_D , at point D of Figure 4.4.2.1 of Report

Scale 0.1 mV/mm = 22×10^{-5} inches per second per chart mm

Chart speed, 125mm/second, or one major division equals 1/25 second

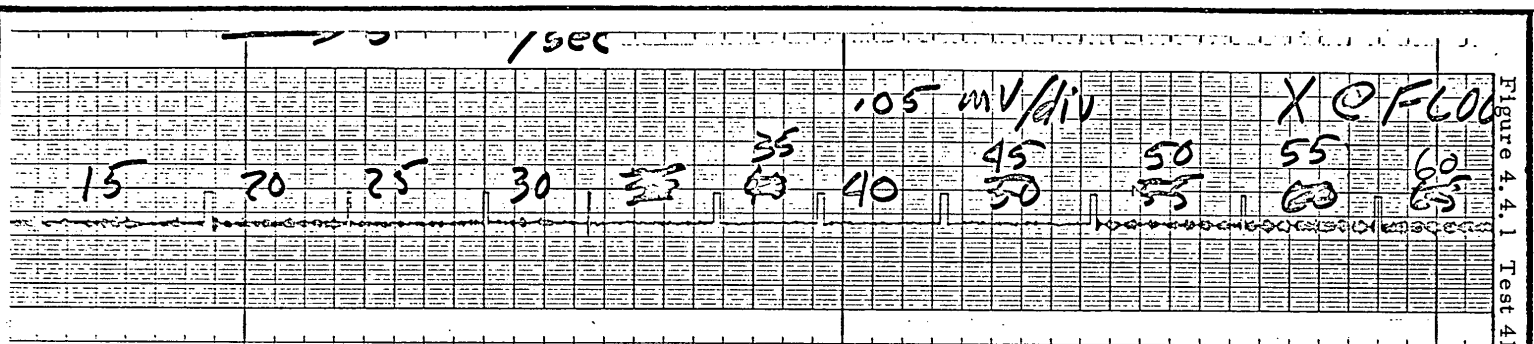
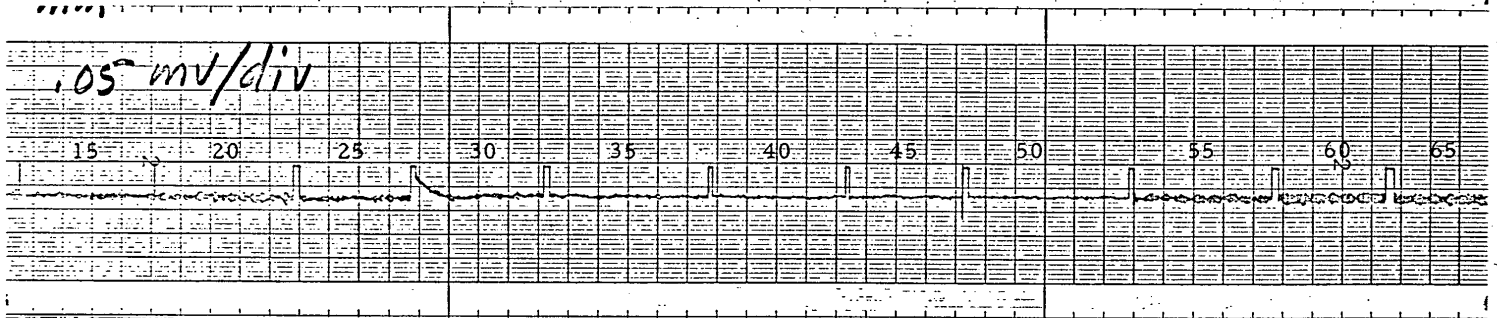


Figure 4.4.1 Test 41-f and 41-g

Test 41-f Beacon Enlarger Test, 28 May 1971, 1420 hrs. Spectral sweep of \bar{X} (horizontal) floor vibration, Blower ON, 5 Hz increments with a GRC 1/3 octave filter. Geophone record of floor ambient \bar{X}_c at point C of figure 4.4.2.1 of report. Scale 0.05 mv/mm = 11×10^{-5} inches per second per chart mm. Note: Horizontal disturbance is primarily at 60 Hz and up.



Test 41-g Beacon Enlarger Test, 28 May 1971, 1435 hrs. Spectral sweep of \bar{X} (horizontal) floor vibration, Blower OFF, 5 Hz increments with a GRC 1/3 octave filter. Geophone record \bar{X}_c of floor ambient, Scale 0.05 mv/mm = 11×10^{-5} inches per second per chart mm.

NOTE: Horizontal disturbance is about the same as Blower ON. Also note that the vertical floor disturbance at 60 Hz (Test 41-a) is approximately 10 X the horizontal disturbance of these tests.

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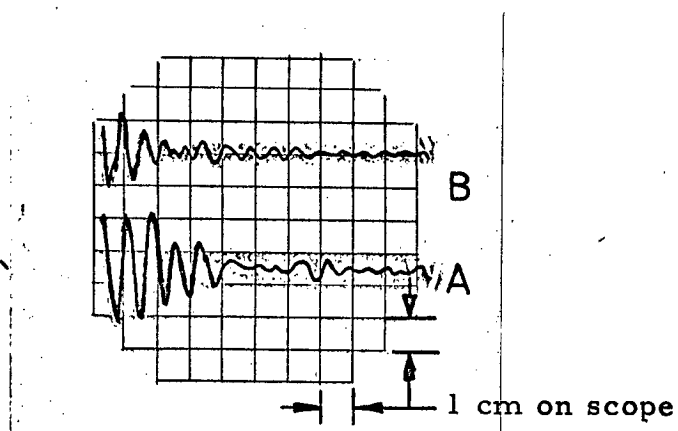
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Figure 4.4.1 Test 44-b

Beacon Enlarger Test, 2 June 1971, 1500 hrs. Record displacement across isolators in response to a heel impact on the floor midway between A and B.

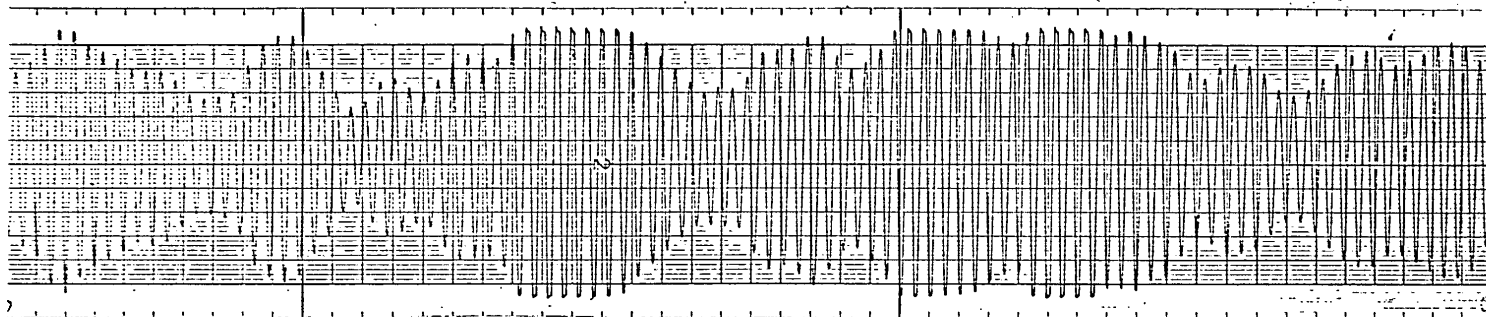


The displacements were measured by the transducers and displayed on the oscilloscope.

Sweep is 100 m sec/cm on scope.

Vertical scale is 50 m v/cm on scope.

Figure 4.4.1. Test 45-h



Test 45-h

Beacon Enlarger Test, 2 June 1971, 1550 hrs. Response of lens mount in X (horizontal) direction to steady state vertical floor, Drive at 10 Hz at [] "worst-case" level. \ddot{X}_D recorded through GRC 1/3 octave filter set at 10 Hz. Geophone record of \ddot{X}_D at point D of Figure 4.4.2.1 of report. Scale 0.05 mv/mm = 11×10^{-5} inches per second. Note the extreme response of the lens mount in the transverse direction which is typical of both lens and easel in response to 10 Hz disturbing which comes through the isolators undiminished.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope

Two series of tests (Test Series 51 and 53) were made on the Dual-Viewing Microstereoscope, Serial No. 4, on 1 June through 3 June 1971. (Note that there was no Test Series 52.) An additional Test Series (54) was made 27 July and 3 August 1971. These tests, their purposes, and the data obtained are described below, in the order in which they were made. Pertinent original data is reproduced in Appendix 4.5.1.

Test Series 51-

Purpose: Measure and record ambient floor disturbances in a typical use situation of the Dual-Viewing Microstereoscope, and record the progression of responses from the floor inputs to various key structural parts of the instrument.

Method: The instrument was set up as though for use, in the open floor area of the Test and Evaluation Branch offices. For the initial tests, the instrument table was equipped with its normal, locking casters. During a portion of the tests, the casters were removed, as noted in the descriptions. EVS-8 geophones were used to measure velocity components of the disturbances, both horizontal and vertical, on the floor and on the instrument. (See Sketch A51)

Test 51-a. Record \ddot{X} (horizontal, long dimension of table) on floor, unfiltered, and at the same time record a spectral analysis from frequency sweep using GRC filter on 1/3-octave bandpass width, sweeping from 5 to 200 Hz. Spectral is also \ddot{X} on floor.

Test 51-b. \ddot{X} on floor, Spectral \ddot{X} on instrument table at point B.

Test 51-c. \ddot{X} on floor, Spectral \ddot{X} on instrument bridge top at point C. In this test, increased amplitude was noted, with amplification at point C so high that record sensitivity had to be reduced to keep information on scale.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test 51-d. \dot{X} on floor, Spectral \dot{X} on instrument platen at point D.

NOTE

In the above tests, the table rested normally on its casters. In the following tests, the table was solidly blocked off the wheels, to evaluate the effect of the caster supports on transmission of vibrations from the floor into the table structure.

Test 51-e. \dot{X} on floor, Spectral \dot{X} on table at point B.

Test 51-f. \dot{X} on floor, Spectral \dot{X} on instrument bridge at point C.

Test 51-g. \dot{X} on floor, Spectral \dot{X} on instrument platen at point D - this test was set up but not recorded. Instead, a series of impulse tests (51g-1 through 51g-5) was made to discover the significance of instrument responses to the support structure both with and without the effect of the casters in the transmission path.

Test 51-h. Slow spectral scan of \dot{X} on table top, with monitor \dot{X} on the instrument bridge, ambient vibration, from 5 through 15 Hz, in 1-Hz increments.

Test 51-i. Same as 51-h, reverse records, to make spectral scan on bridge, and monitor \dot{X} on table top.

NOTE

For the following tests, the casters were removed from the table, allowing the table legs to rest directly on the floor.

Test 51-j. Spectral \dot{X} scan on table, monitor \dot{X} on floor.

Test 51-k. Impulse reaction, \dot{X} on table top.

Test 51-l. Low-frequency spectral scan, \dot{X} on table at point B, monitor \dot{X} on floor.

Test 51-m. Spectral scan, \dot{X} on instrument bridge at point C, monitor \dot{X} on floor.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test 51-n. Spectral scan, \dot{X} on instrument platen at point D, monitor \dot{X} on floor.

NOTE

Observation of the data from the above tests indicated that absence of the casters makes a higher frequency suspension, through which disturbances pass at higher frequencies than when the load is supported on the 7 to 9 Hz suspension afforded by the wheels and their axles, etc. For the balance of the tests, the instrument was returned to its "as-used" condition, with the caster assemblies replaced.

Test 51-o. Spectral \dot{X} on platen, monitor \dot{X} on floor.

Test 51-p. Spectral \dot{Y} on platen, monitor \dot{Y} on floor.

Test 51-q. Record \dot{X} on platen, filtered at 25 Hz, with and without operator contact with the instrument.

Test 51-r. Spectral \dot{Y} on table, monitor \dot{Y} on floor.

Test 51-s. Spectral \dot{Y} at bridge, monitor \dot{Y} on floor.

Test 51-t. Spectral \dot{Y} on the floor, with monitor \dot{Y} also on floor. This test was made to recheck nature of ambient disturbances.

Test 51-u. Spectral \dot{Z} on floor, monitor \dot{Z} on floor.

Test 51-v. Spectral \dot{Z} on table, monitor \dot{Z} on floor.

Test 51-w. Spectral \dot{Z} at platen, monitor \dot{Z} on floor.

Test 51-aa. Spectral \dot{Z} at bridge, monitor \dot{Z} on floor. (This was the last test made on 2 June)

Test 51-ab. (Resume testing 3 June 1971, at 8:30 a.m.) Spectral \dot{Z} on floor, with monitor \dot{Z} also on floor, to check nature of ambient disturbances being transmitted to the floor of the building at this time of day.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test 51-ac. Low-frequency spectral scan from 10 Hz to 20 Hz, \ddot{Z} on floor.

Test 51-ad. Drive the floor at 10 Hz with the \ddot{Z} response of the floor being recorded both filtered at 10 Hz, and unfiltered.

Test 51-ae. Drive the floor at 10 Hz with the \ddot{Z} response of the floor recorded unfiltered, and filtered at 20 Hz. Data shows that 10 Hz drive does not excite any 20 Hz response. The system of the floor is quite linear.

Test 51-af. Drive floor at frequencies up to 18 Hz, record \ddot{Z} on floor unfiltered and filtered at 10 Hz. The data shows that 18 Hz drive does not excite any appreciable 10 Hz response, as expected.

Test Series 53-

Purpose: Monitor and record the relative displacements of significant points on the Dual-Viewing Microstereoscope, to determine their effect on image disturbance under various operating conditions.

The resolution capability stated by the manufacturer for this instrument is 300 lines per mm at maximum (75X) magnification.

Method: Displacement transducers were set up to measure the relative displacements between significant points on the instrument, such as between the platen and the instrument table. The reproductions of test sketches 53-1 and 53-2 (See Figures show the general arrangement and locate the points referred to in the following test descriptions.

Test 53-a. Set up transducers to measure the relative Z dimension between the table and the top of the bridge support at "A," to show the amount of rotation of the bridge end at its single point of support.

Note: The transducer calibration is 1 volt output signal = .01 inch of movement.

A .04-volt, or 400 microinch movement is observed due to slight finger pressure transversely on the bridge, operator elbow pressure on the table or touching the instrument controls.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test 53-a. (Contd.)

Record the displacement response to a finger tap on the top of the instrument eyepiece structure in a transverse direction. The response is recorded by oscilloscope photo 53-a, at a sensitivity of 200 mV per cm on each channel, and a sweep rate of 100 milliseconds per cm. The resonant frequency appears to be 26 Hz.

NOTE

During the relative displacement tests of the instrument, a No. 11-795 Foepl Vibration Calibration Graticule was placed in the microscope field of view, at 75X magnification, for visual observation. This is a 2- x 1-inch glass slide, opaque except for a small central rectangle. In this rectangle are 20 pairs of 0.001 inch dots converging on a single dot. Distance between each pair of dots increases by 0.001 inch to a maximum of 0.02 inch in the last pair. Pairs of dots are equally spaced over 0.25 inch. When the slide vibrates under the microscope, the amount of vibration can be estimated by observing which pair of dots appears to merge into a single dot. It is a useful visual tool for quick comparison of the effects of different vibration disturbances. The device is hereafter referred to as the vibration graticule.

Test 53-b. Visually observe scope signal of displacement at "A," while operator observes vibration graticule through the microscope and Ling Vibration Driver mounted on table at "C" drives table in transverse X-direction at 16 Hz. This gives a correlation between the deflection seen in Test 53-a, and the resulting, or equivalent, image shift.

Observation: For a 10^{-3} inch image shift, seen in the vibration graticule, the scope signal is 48 mV, which is equivalent to $.48 \times 10^{-3}$ inch relative displacement at "A." This relative displacement is in the Z direction and represents rocking of the instrument bridge on its pivot.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test 53-c. Same test as 53-b, but measure relative displacement in the X direction at "B," to see if part of the image motion is due to platen X motion.

Observation: For 10^{-3} image shift, the scope signal is 250 mV, which is equivalent to 2.5×10^{-3} inch. This shows that the most troublesome motion is the lateral, or X-direction movement of the platen.

Test 53-d. Having found that almost all of the X-motion is occurring at the platen X-drive mounting, it is found that this motion can be reduced almost to zero by applying a piece of heavy tape as a damper over the space between the platen and the table top at the end of the platen, as shown in the reproduction of test sketch 53-1. The following scope photos illustrate this:

- 53-d-1 16Hz drive, no tape damper in place
- 53-d-2 16Hz drive, tape at both ends of the platen
- 53-d-3 16Hz drive, tape only at driving end of platen

Test 53-e. Sweep frequencies with the Ling Vibration Driver mounted at "C," driving in the X direction.

Observed only two resonant frequencies of any importance, 18Hz and 25Hz.

Image vibration due to the 18 Hz frequency can be eliminated with the tape damper discussed in Test 53-d. Image vibration due to the 25 Hz frequency can be eliminated with a wood wedge under the bridge structure at the single support-point end, as shown in the reproduction of sketch 53-1.

These observations are supported by the following records: (In each case the drive - 18Hz or 25Hz - was set to a level that produced graticule vibration of .001 inch.)

- 53-e-1 18 Hz, no tape, lower trace is platen X, upper trace is bridge Z at "A," in all scope photos described in this series.

- 53-e-2 18Hz, with tape

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test 53-e. (Contd.)

- 53-e-3 25 Hz, without tape, without wood wedge
- 53-e-4 25 Hz, with tape, without wood wedge
- 53-e-5 25 Hz, without tape, with wood wedge

Test 53-f. Monitor the relative displacements with floor drive at 10 Hz by the DMI Vibration Driver, to simulate building vibrations caused by outside disturbances. Measurement points and conditions are the same as for Tests 53-b through 53-e.

- Scope 53-f-1 Without tape, without wedge, 10 Hz floor drive
- Scope 53-f-2 Without tape, without wedge, ambient floor vibration only
- Brush record 53-f-1: Made to check the floor amplitude. It appears to be 35 microinches at 10 Hz
- Scope 53-f-3 With tape, with wedge, ambient floor vibration
- Scope 53-f-4 With tape, with wedge, 10 Hz floor drive

Test 53-g. Simulate operator-caused disturbances to show the improvement possible in reducing the effect of such disturbances on image motion from better structural support and damping.

- Scope 53-g-1a) With wood wedge and tape applied
- Scope 53-g-1b)
- Scope 53-g-2 Without wedge but with tape
- Scope 53-g-3 Without wedge or tape

Observation of the vibration graticule at the same time indicates an improvement in apparent image motion of at least 5-to-1, from about .0025 inch, to less than about .0005 inch, with the damping and support added.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test Series 54- (27 July 1971)

Purpose: Measure and record the responses of the parts of the Dual-Viewing Microstereoscope previously found to affect image motion, when the floor is driven sinusoidally in the vertical mode to the vertical amplitudes predicted as the possible worst-cases by the [] report at the selected test frequencies of input. STAT

Method: The DMI Vibration Driver was used to excite the floor system at frequencies of 10, 12, 18, and 25 Hz, at the worst-case levels of the D'Appolonia Report. The vertical velocity component of floor vibration was sensed by an EVS-8 geophone, with its signal processed by the GRC Vibration Analyzer. To set the drive level, the geophone signal was filtered, 1/3-octave bandpass, at the frequency desired for the drive.* The drive frequency was slowly increased until the filtered geophone output peaked, indicating response. The amplitude of floor drive at any given frequency was controlled by the position of the Vibration Driver, relative to the center of the floor panel. Responses on the instrument were measured by relative displacement transducer, one set up to measure the displacement of the platen in the Y direction relative to the table top. The other transducer was set up to measure the displacement of the top of the bridge, relative to the table top. Platen displacement is noted as Y_b , and bridge (rocking) displacement is noted as Z_b .

Test 54a-1 through Test 54a-11. This series of tests was made to calibrate the instrumentation and find the proper position for the Vibration Driver on the floor panel to produce the desired amplitude of floor excitation at each driving frequency of interest. The position differed for each driving frequency. In addition to the calibration of the test set up, records were obtained of ambient floor vibrations (\dot{Z}_a , Test 54a-1) under normal conditions, and ambient floor vibrations with vigorous walking nearby (\dot{Z}_a , Test 54a-2) which are good data for power spectral analysis. Note that position of the floor geophone is noted as (A) in Figure 4.5.5.1 of the report.

In Test 54a-10, while driving the floor at 18 Hz, and at the predicted worst-case amplitude, the Vibration Graticule was observed in the microscope at full magnification. No image blurring was detected.

*The drive level was set in this manner at the beginning of each excitation test, but during the test recording the filter was off, with the floor response recorded "all-pass."

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

Test 54b-1. This was start of the regular test procedure. Record ambient \dot{Z}_a with the response Y_b .

Test 54b-2. Record ambient \dot{Z}_a with the response Z_b .

Test 54b-3. Same as 54b-1, but with vigorous walking nearby.

Test 54b-4. Same as 54b-2, with vigorous walking.

Test 54b-5.)

Test 54b-6.) Tests not valid - geophone signal not filtered at level setting.

Test 54b-7.)

Test 54b-8. Test not valid, drive level not correct. Destroy record.

Test 54b-9. Drive floor at 25Hz, record \dot{Z}_a floor, with Z_b response. (Low level)

Test 54b-10. Drive floor at 25Hz, record \dot{Z}_a floor, with Z_b response.

Test 54b-11. Drive floor at 25Hz, record \dot{Z}_a floor, with Y_b response.

Test 54b-12. Drive floor at 18Hz, record \dot{Z}_a floor, with Y_b response.

Test 54b-13. Drive floor at 18Hz, record \dot{Z}_a floor, with Z_b response.

Test 54b-14. Drive floor at 18Hz, record \dot{Z}_a floor, with Y_b response.

Test 54b-15. Drive floor at 18Hz, record \dot{Z}_a floor, with Z_b response.

Test 54b-16. Drive floor at 25Hz, record \dot{Z}_a floor, with Y_b response.

Test 54b-17. Drive floor at 25Hz, record \dot{Z}_a floor, with Z_b response.

Test 54b-18. Drive floor at 10Hz, record \dot{Z}_a floor, with Z_b response.

Test 54b-19. Drive floor at 10Hz, record \dot{Z}_a floor, with Y_b response.

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4.5 Detail Description, Vibration Tests - Bausch & Lomb Dual-Viewing Microstereoscope (Contd.)

(Additional tests made 3 August 1971 - to compare floor driving response with actual visual observation of Vibration Graticule image)

Test 54c-1. Drive floor at 25Hz, record \dot{Z}_a floor and Y_b response.

Observation: The image moves significantly, more than .001 inch peak-to-peak, at the 25Hz resonance. The image moves slightly more, and resonance actually seems to occur at about 24.5 Hz.

Test 54c-2. Repeat 54c-1 at the slightly lower observed resonant frequency, 24.7 Hz. Record Y_b .

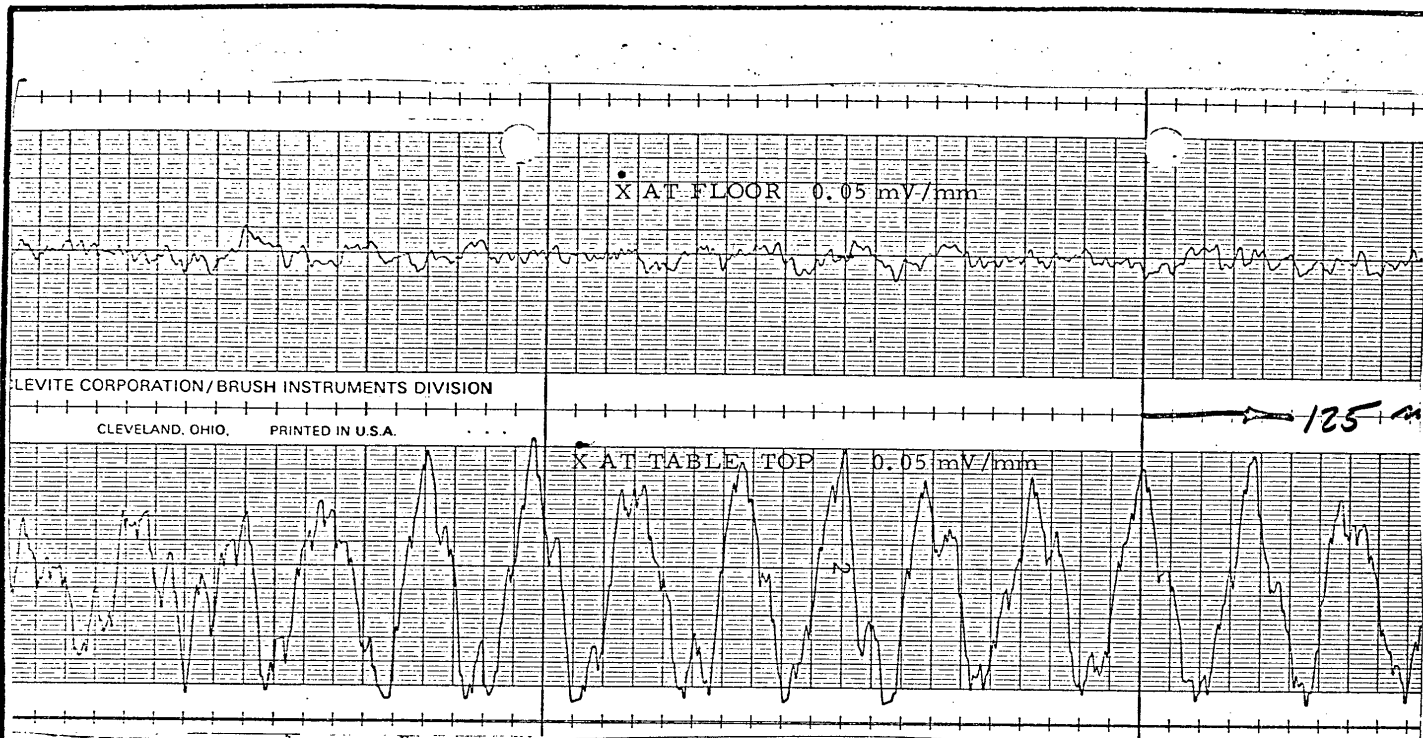
Test 54c-3. Same as 54c-2, record Z_b .

(The following tests are impulse response tests made on the instrument platen, to record the effects undamped, and damped by a piece of heavy tape.)

Test 54c-4. Undamped

Test 54c-5. Damped with gun tape.

Test 54c-6. Damped with gun tape.



Test 51-b

DVM Tests in T & EB Lab, 1 June 1971, 1350 hrs.

Response at corner of table top, in X direction to floor ambient vibrations.

Geophone record of floor, X-direction at a point beneath the table,

Geophone record of table, X-direction at corner of table top,

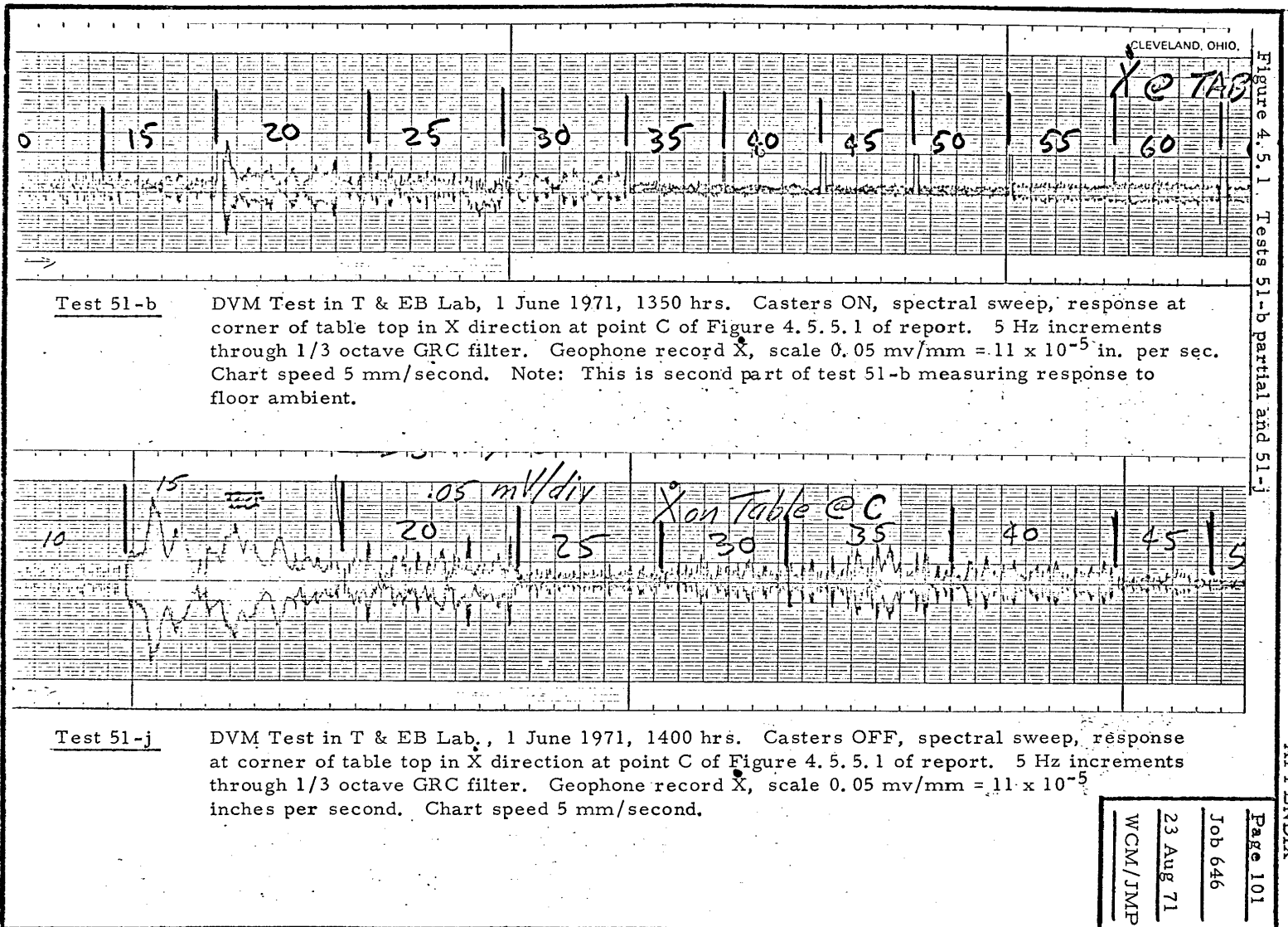
both records .05 mV/mm = 11×10^{-5} inches per second per chart mm

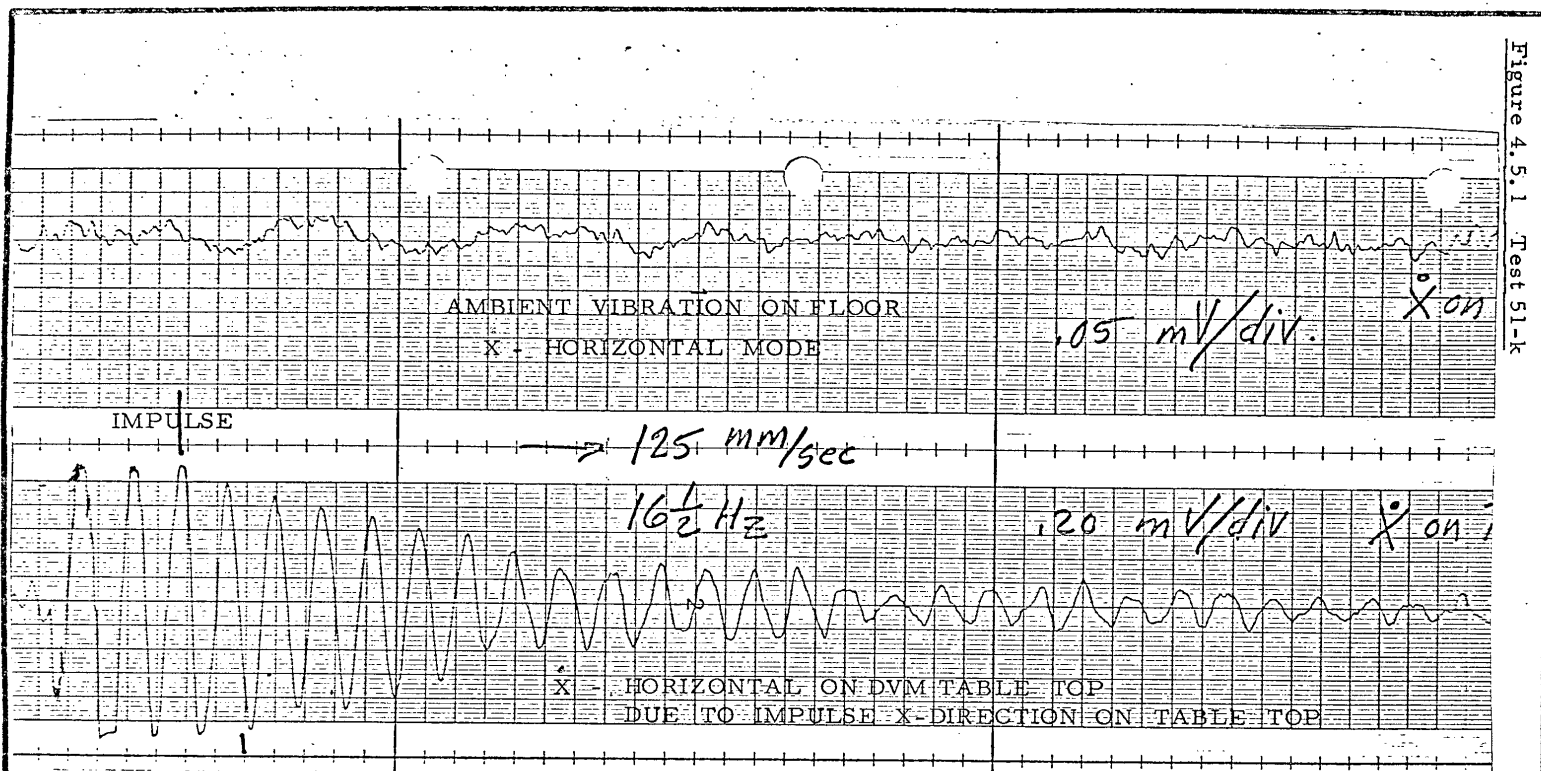
Chart speed, 125mm/second, or one major division equals 1/25 second

The observed major resonance is at $7 \frac{1}{4}$ Hz.

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Test 51-k

DVM Test in T & EB Lab, 1 June 71, 1400 hrs.

Response at table top to impulse made with the hand in X-direction against side of table. Wheels have been removed from table.

Geophone record of floor X-direction velocity at a point beneath the table,

 $.05 \text{ mV/mm} = 11 \times 10^{-5} \text{ inches per second per chart mm}$

Geophone record of table X-response at corner of table top,

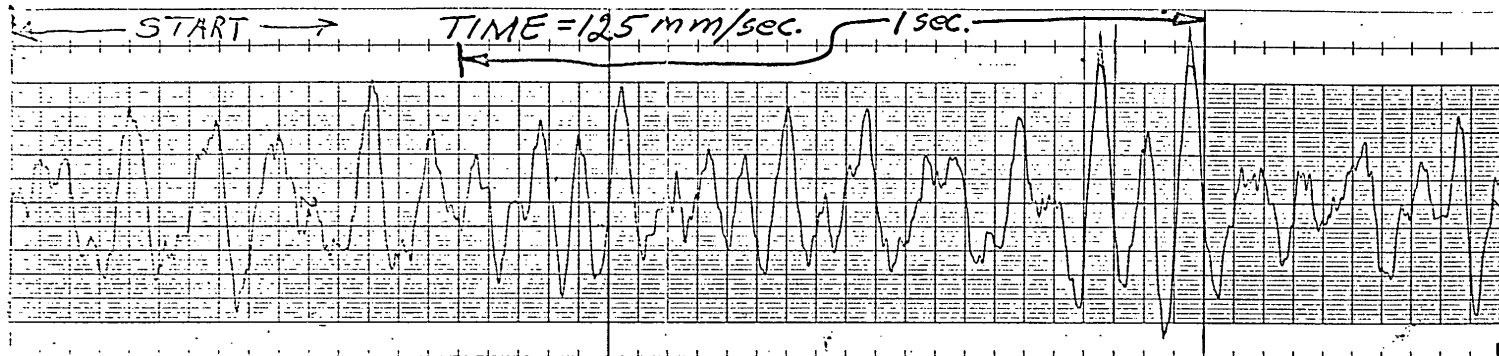
 $0.2 \text{ mV/mm} = 44 \times 10^{-5} \text{ inches per second per chart mm}$

Chart speed, 125mm/second, or one major division equals 1/25 second

Decay time of response is 2 seconds

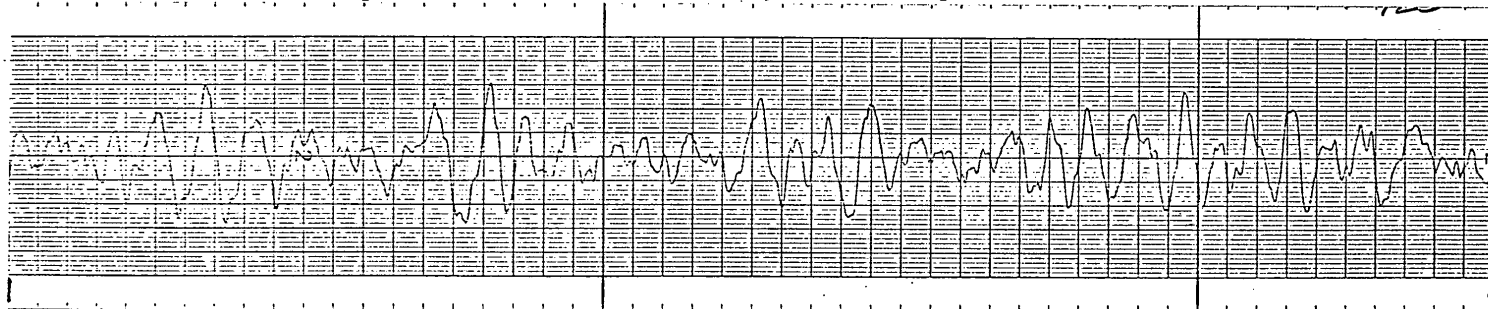
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Test 51-ab

DVM Tests in T & EB Lab, 3 June 1971, 0830 hrs.
Ambient floor vibration, full wave recording
Geophone record of \ddot{Z} at point (A) on Figure 4.5.2.1
Scale 0.1 mV/mm which is equivalent to 22×10^{-5} inches per second per Chart mm
Chart speed 125mm/second, or one major division equals 1/25 second

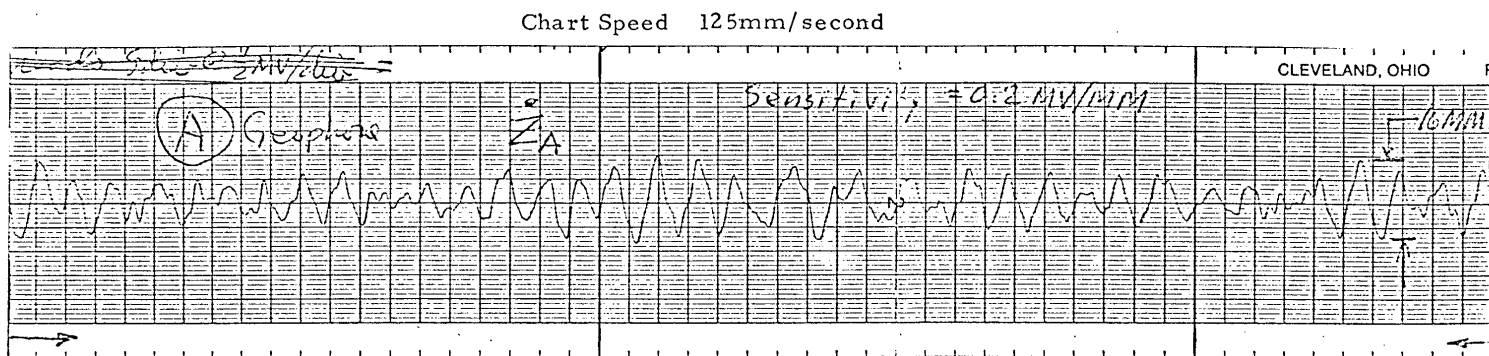


Test 51-u

DVM Tests in T & EB Lab, 2 June 1971, 1630 hrs.
Ambient floor vibration, full wave recording
Geophone record of \ddot{Z} at point (A) on Figure 4.5.2.1
Scale 0.10 mV/mm which is equivalent to 22×10^{-5} inches per second per Chart mm
Chart speed 125mm/second, or one major division equals 1/25 second

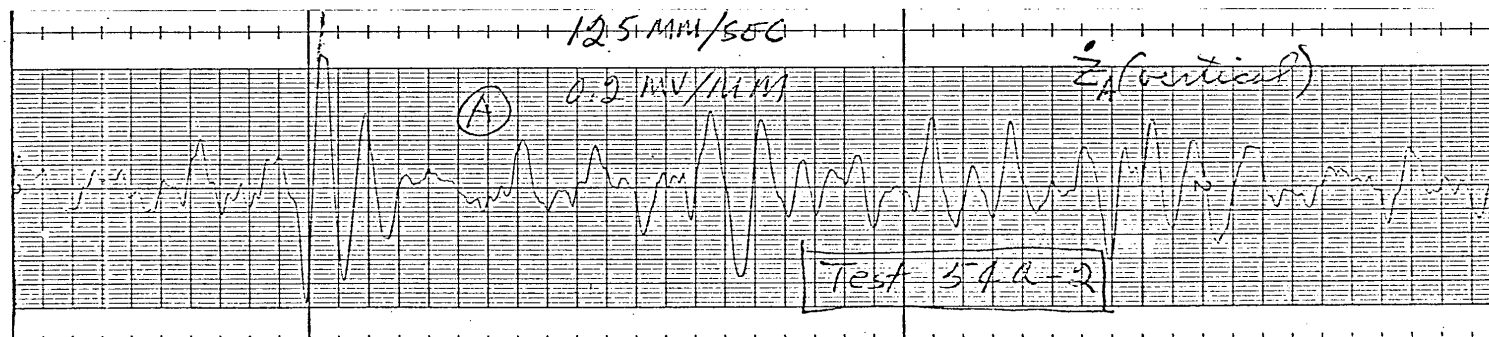
Figure 4.5.1, Test 51-u and Test 51-ab

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Test 54a-1

DVM Tests in T & EB Lab, 28 July 1971, 1000 hrs.
 Ambient floor vibration, full wave recording, normal office activity
 Geophone record of \dot{Z}_A at point A Figure 4.5.2.1
 Scale 0.2 mV/mm which is equivalent to 44×10^{-5} inches per second per chart mm
 Chart speed is 125mm/second, or one major division equals 1/25 second



Test 54a-2

DVM Tests in T & EB Lab, 28 July 1971, 1000 hrs.
 Ambient floor vibration, full wave recording, walking near instrument
 Geophone record of \dot{Z}_A at point A Figure 4.5.2.1
 Scale 0.2 mV/mm which is equivalent to 44×10^{-5} inches per second per chart mm
 Chart speed is 125mm/second, or one major division equals 1/25 second

Figure 4.5.1, Test 54a-1 and Test 54a-2

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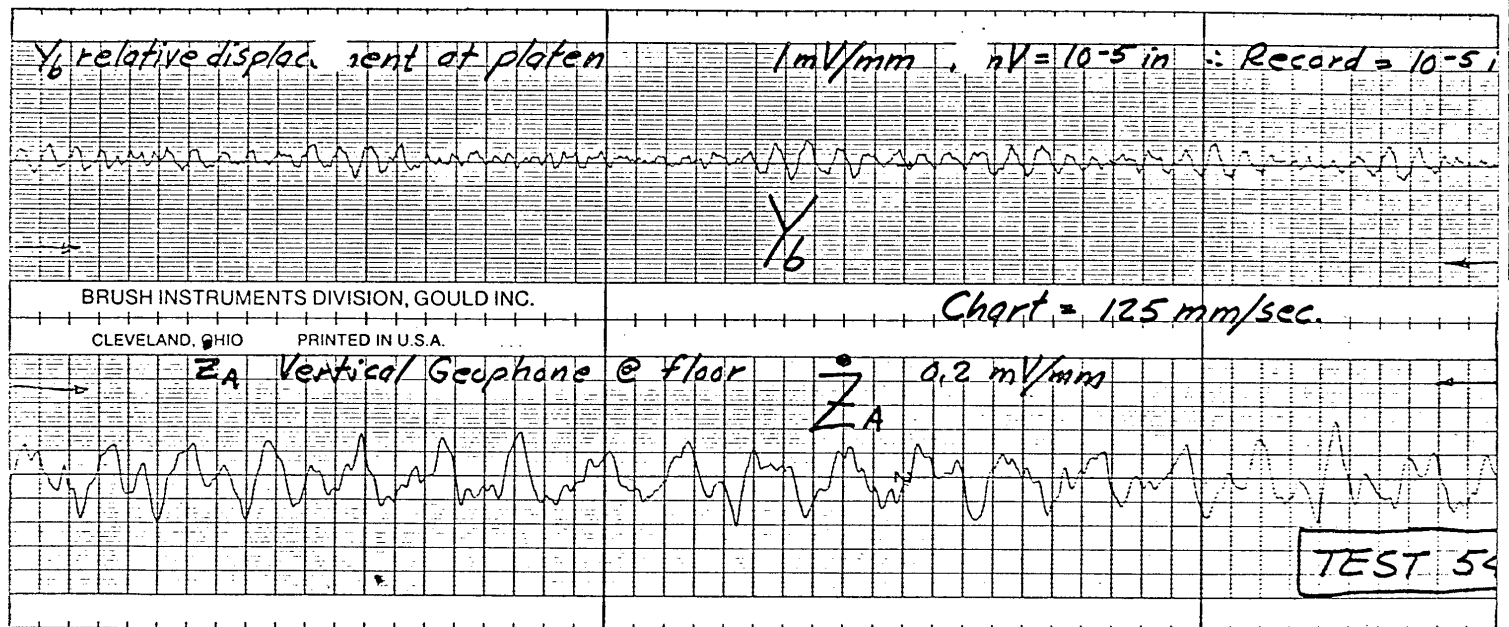


Figure 4.5.1, Test 54b-1

Test 54b-1

DVM Tests in T & EB Lab, 28 July 1971, 1000 hrs.

Comparison of ambient floor vibration and response of platen in Y direction displacement, both full wave recordings made simultaneously during normal office activity

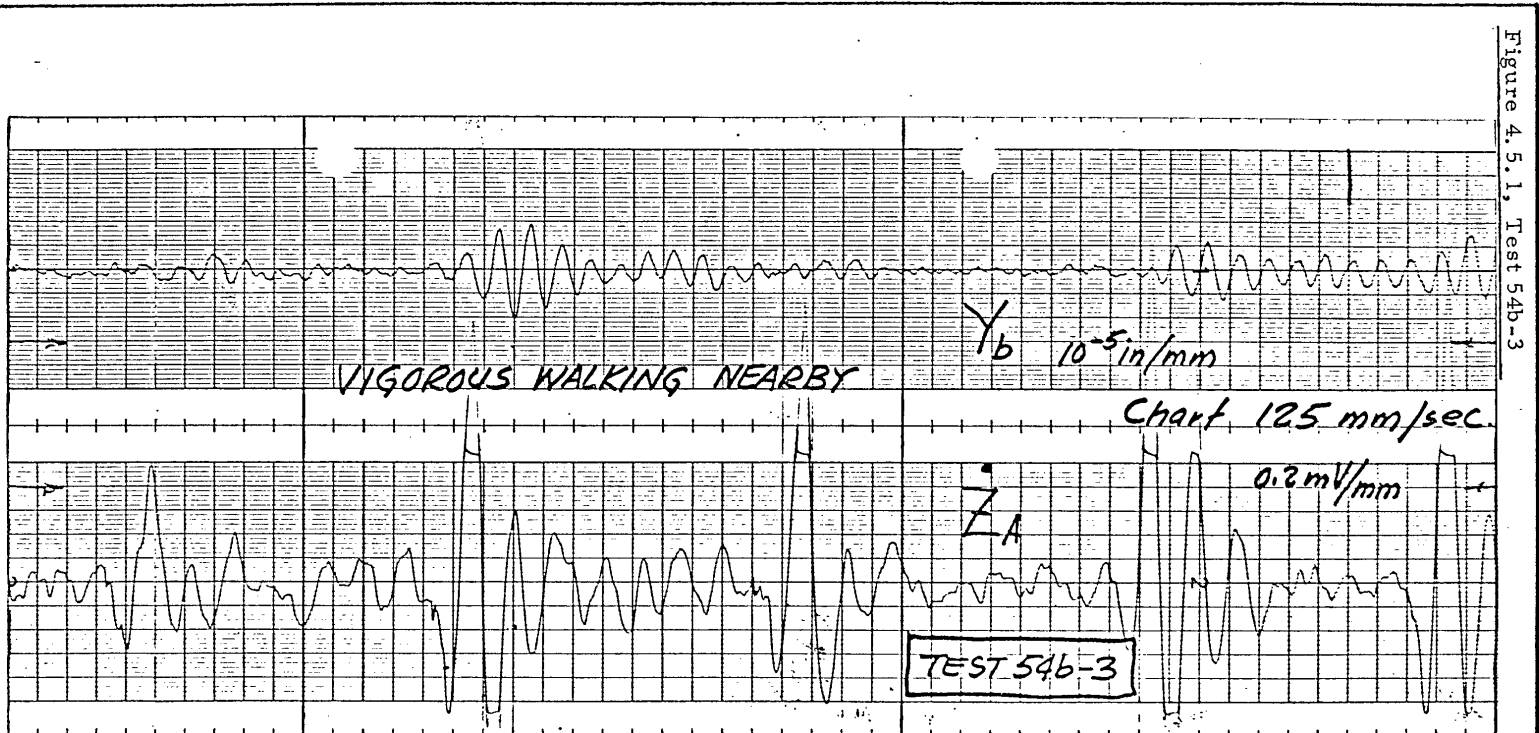
Displacement transducer record of Y_b at point B of Figure 4.5.2.1

Scale of Y_b , 1 mV/mm = 1×10^{-5} inches/mm displacement

Geophone record of Z_a at point A of Figure 4.5.2.1

Scale of Z_a , 0.2 mV/mm = 44×10^{-5} inches per second per chart mm, velocity
Chart speed, 125mm/second, or one major division equals 1/25 second

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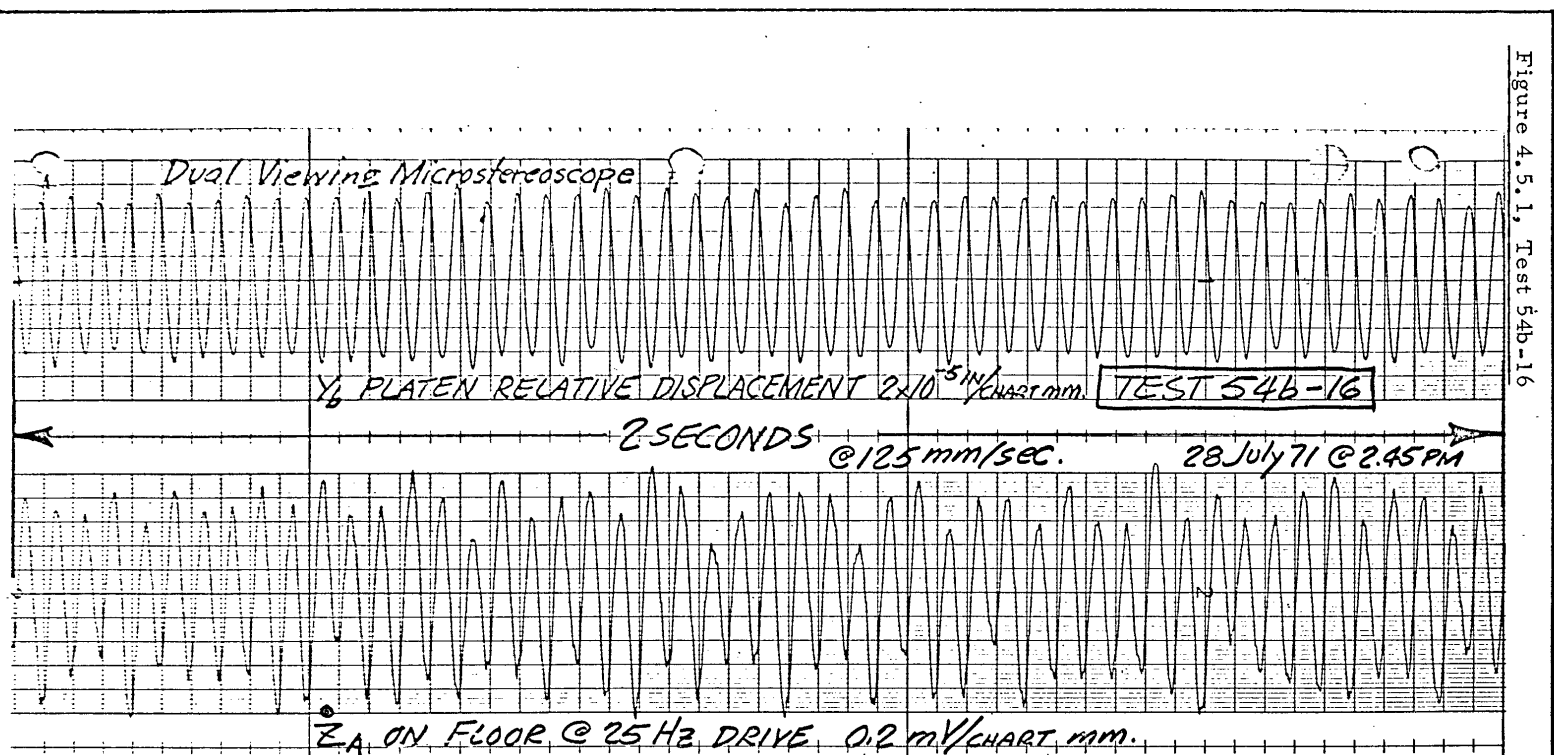


Test 54b-3

DVM Tests in T & EB Lab, 28 July 1971, 1000 hrs.
 Comparison of floor vibration and response of platen in Y direction displacement, both full wave recordings made simultaneously during vigorous walking nearby.
 Displacement transducer record of Y_b at point B of Figure 4.5.2.1
 Scale of Y_b , $1 \text{ mV/mm} = 1 \times 10^{-5} \text{ inches/mm displacement}$
 Geophone record of Z_a , $0.2 \text{ mV/mm} = 44 \times 10^{-5} \text{ inches per second per chart mm}$
 Chart speed, 125mm/second, or one major division equals 1/25 second

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Test 54b-16

DVM Tests in T & EB Lab, 28 July 1971, 1445 hrs.

Response to driven floor vibration @ 25 Hz of platen in Y direction. Floor drive at "worst-case" level.

Displacement transducer record of Y_b at point B of Figure 4.5.2.1

Scale of Z_b , $2 \text{ mV/mm} = 2 \times 10^{-5}$ inches per chart mm displacement

Geophone record of Z_a , $0.2 \text{ mV/mm} = 44 \times 10^{-5}$ inches per second per chart mm

Chart speed, 125mm/second, or one major division equals 1/25 second

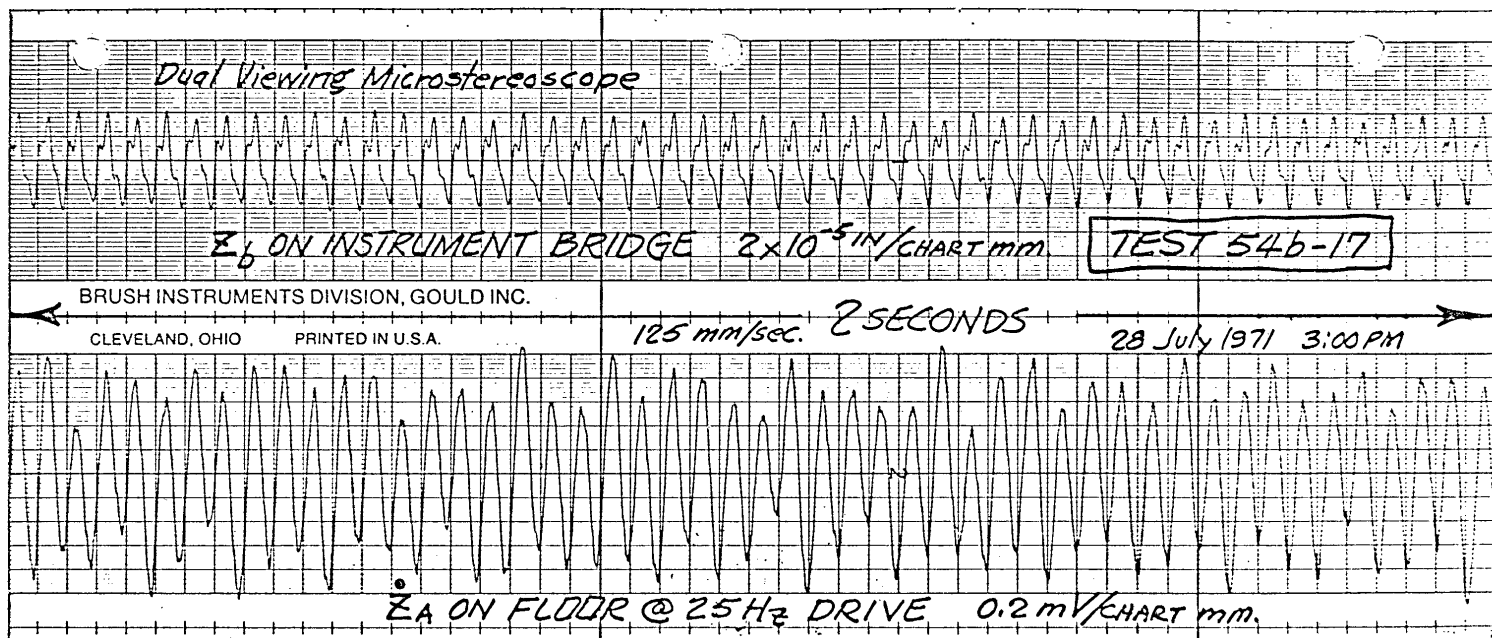


Figure 4.5.1 Test 54b-17

Test 54b-17

DVM Tests in T & EB Lab, 28 July 1971, 1500 hrs.
 Response to driven floor vibration at 25 Hz of corner of bridge. Floor drive at "worst-case" level.
 Displacement transducer record of Z_b at point B₂ of Figure 4.5.2.1
 Scale of Z_b , 2 mV/mm = 2×10^{-5} inches/mm displacement
 Geophone record of \dot{Z}_a , 0.2 mV/mm = 44×10^{-5} inches per second per chart mm
 Chart speed, 125mm/second, or one major division equals 1/25 second

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5.0 Data for Building Vibration Specification Recommendation

The tests necessary to analyze the various items of equipments also required recording of ambient floor vibration simultaneously with equipment response. Therefore, a great number of floor ambient vibration measurements are available, made over the period from 18 May 1971 through 25 August 1971. Of course, there was no systematic attempt to make tests of the floor which could be correlated with time of day, type of activity, etc. However, there were a sufficient number of tests made so that information useful in evaluating a suitable building vibration environment can be derived when used in combination with the [redacted] and other information.

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Additionally, brief tests were made of floors in three other type structures for comparison purposes. Also, contact was made with various structural engineering authorities for data on building vibration environment. Except for earthquake engineering investigations, which are not applicable, no codification of building vibration environment data has been established as yet.

5.1 Tests of Ambient Vibration at Site Made During Program

Ten typical power density spectra were calculated for the ambient tests made in connection with the equipment specifications. Over 40 recordings of floor ambient vibration were made during the equipment tests, but of course they were not all subjected to calculation as it was not necessary for understanding the equipment difficulty. A list of the power density spectra of floor ambient vibration follows:

| | |
|-----------------------|-------------|
| Report Figure 4.2.6.3 | Test 23a-3 |
| Report Figure 4.2.6.5 | Test 24b-11 |
| Report Figure 4.4.6.1 | Test 41e |
| Report Figure 4.5.6.2 | Test 54a-1 |
| Report Figure 4.5.6.4 | Test 54b-1 |
| Appendix Figure 5.1.1 | Test AMB-5 |
| Appendix Figure 5.1.1 | Test 41-a |
| Appendix Figure 5.1.1 | Test 51-u |

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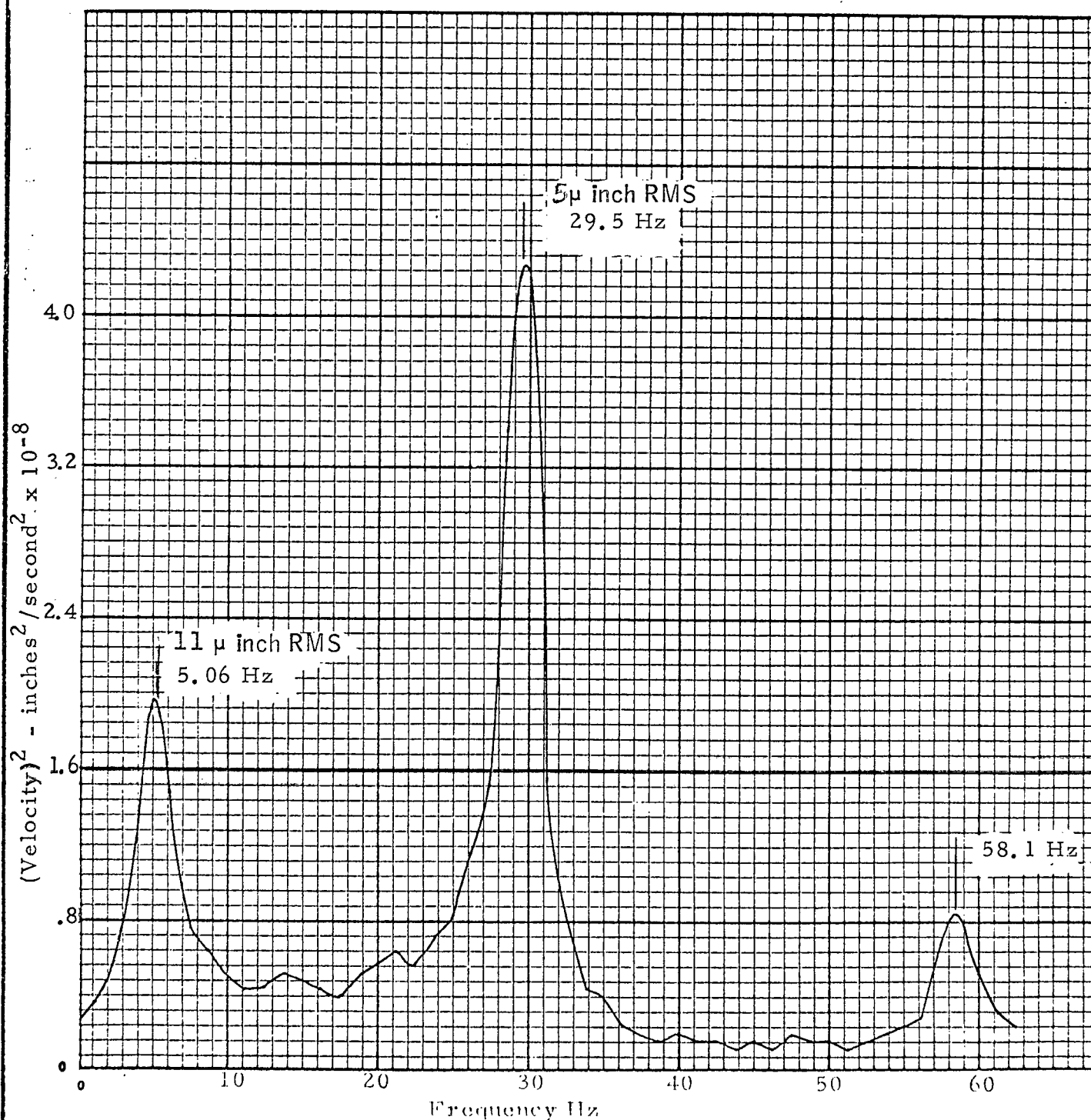
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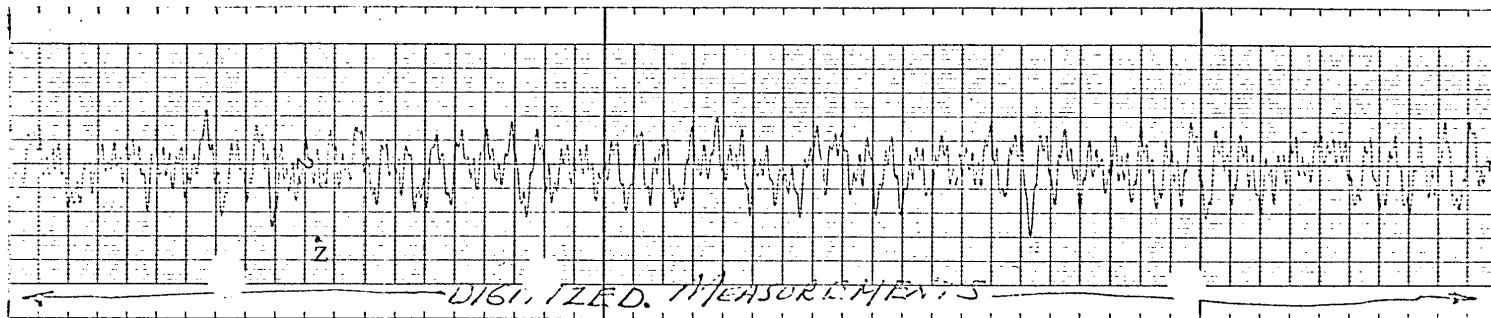
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Figure 5.1.1 - Power Density Spectrum, Floor Ambient Vibration

Test AMB-5, 10X, 20X, 40X Enlarger #3, 21 May 1971, 1115

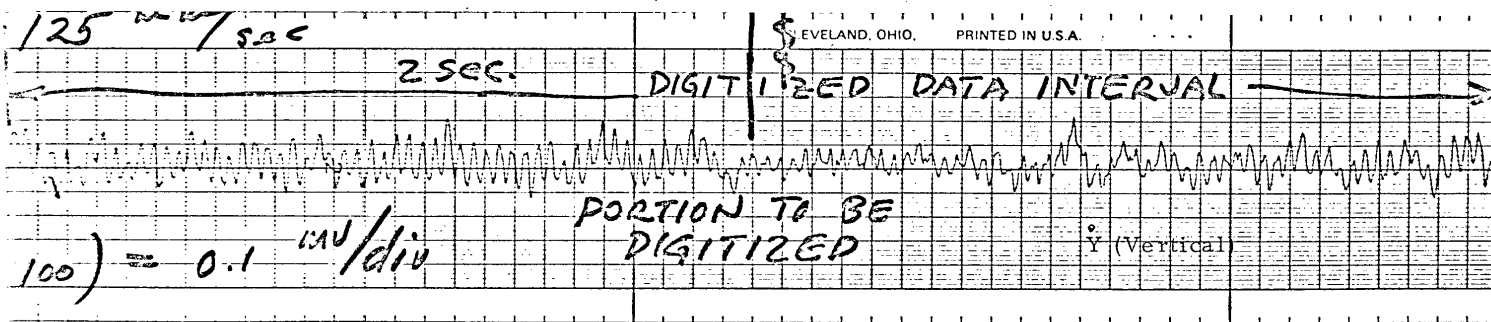
Vertical Vibration Recorded on floor adjacent to equipment

 $\sigma_V^2 = .3407 \times 10^{-5} \text{ in}^2/\text{sec}^2$, $\sigma_D^2 = .6051 \times 10^{-9} \text{ in}^2$, $\sigma_D = .2461 \times 10^{-4} \text{ in}$.



Test AMB-5

Ambient floor vibration record made in 10X, 20X, 40X Kodak Enlarger Room on 21 May 1971, 1115 hrs., for purpose of power spectrum analysis
Record was made in connection with Test 1I-20 of Appendix, Section 4.1
Scale of geophone record, Z, $0.01 \text{ mV/mm} = 2.2 \times 10^{-5}$ inches per second per chart mm
Chart speed, 125mm/second, or one major division = 1/25 second



Test 41-a

Ambient floor vibration record made in Beacon Enlarger Room on 28 May 1971, 1315 hrs., Equipment Blower ON
Scale of geophone record, Y (vertical), $0.1 \text{ mV/mm} = 22 \times 10^{-5}$ inches per second per chart mm
Chart speed, 125mm/second, or one major division = 1/25 second

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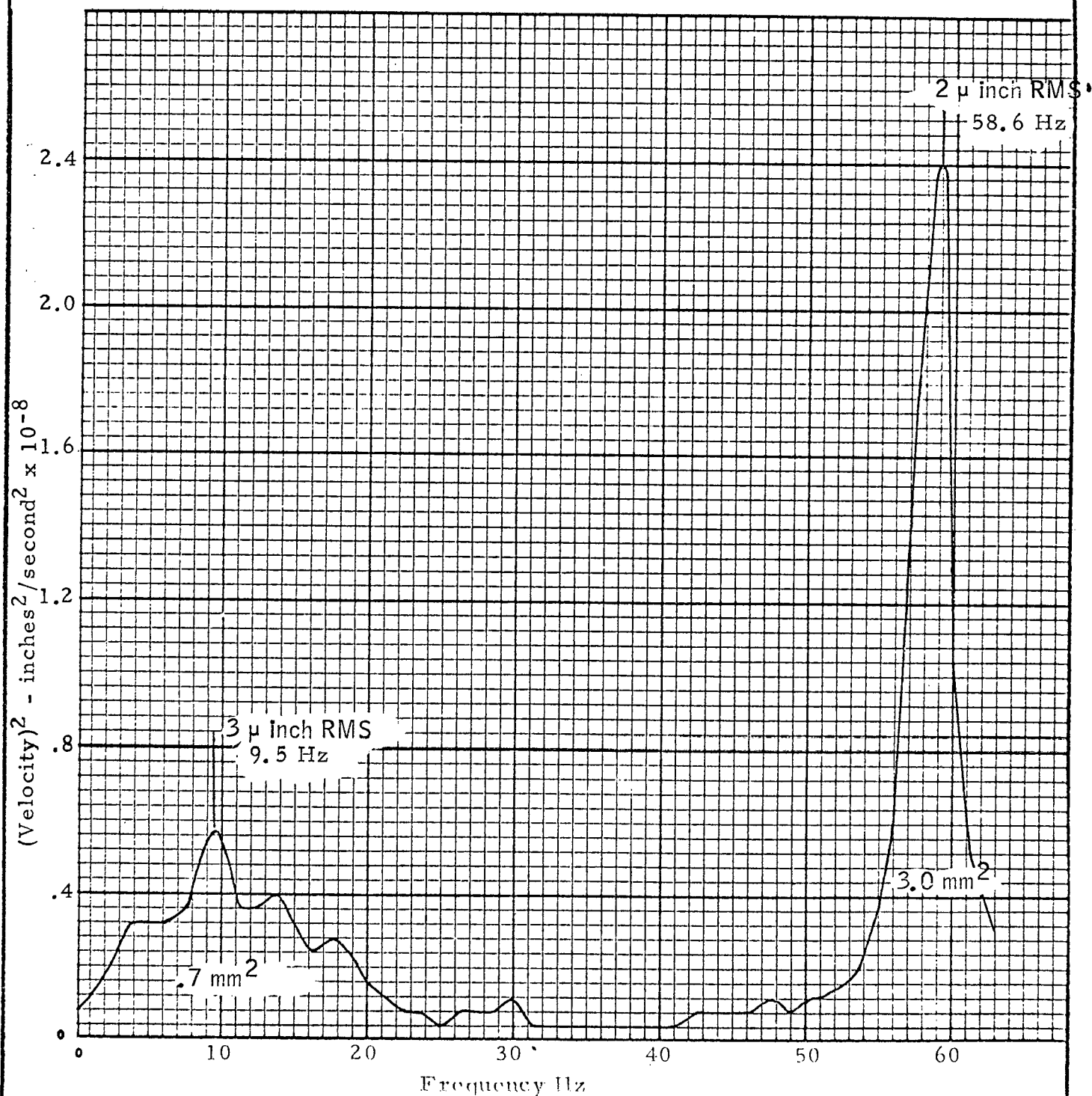
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Figure 5.1.1 - Power Density Spectrum, Floor Ambient Vibration

Test 41-a, Beacon Enlarger #1, 28 May 1971

Vertical Vibration recorded on the floor adjacent to equipment

$$\sigma_v^2 = .5132 \times 10^{-6} \text{ in}^2/\text{sec}^2, \sigma_D^2 = .7593 \times 10^{-10} \text{ in}^2, \sigma_D = .8714 \times 10^{-5} \text{ in.}$$



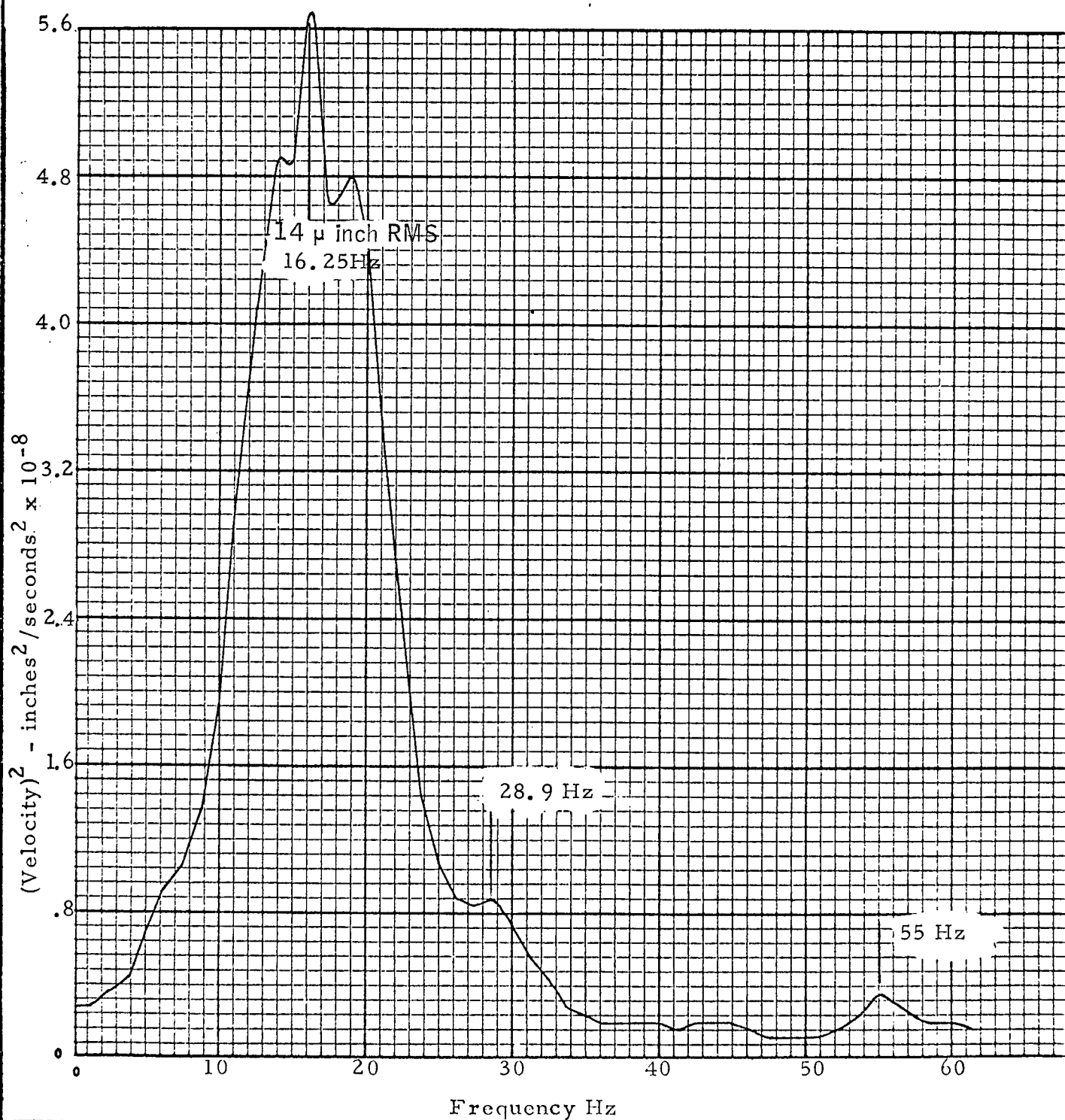
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Figure 5.1.1 - Power Density Spectrum, Floor Ambient Vibration

Test 51-U, T & EB Lab, 2 June 1971, 1630

Vertical Vibration Recorded in the center of the floor slab.

$$\sigma_v^2 = .6100 \times 10^{-5} \text{in}^2/\text{sec}^2, \sigma_D^2 = .1170 \times 10^{-8} \text{in}^2, \sigma_D = .3422 \times 10^{-4} \text{in.}$$

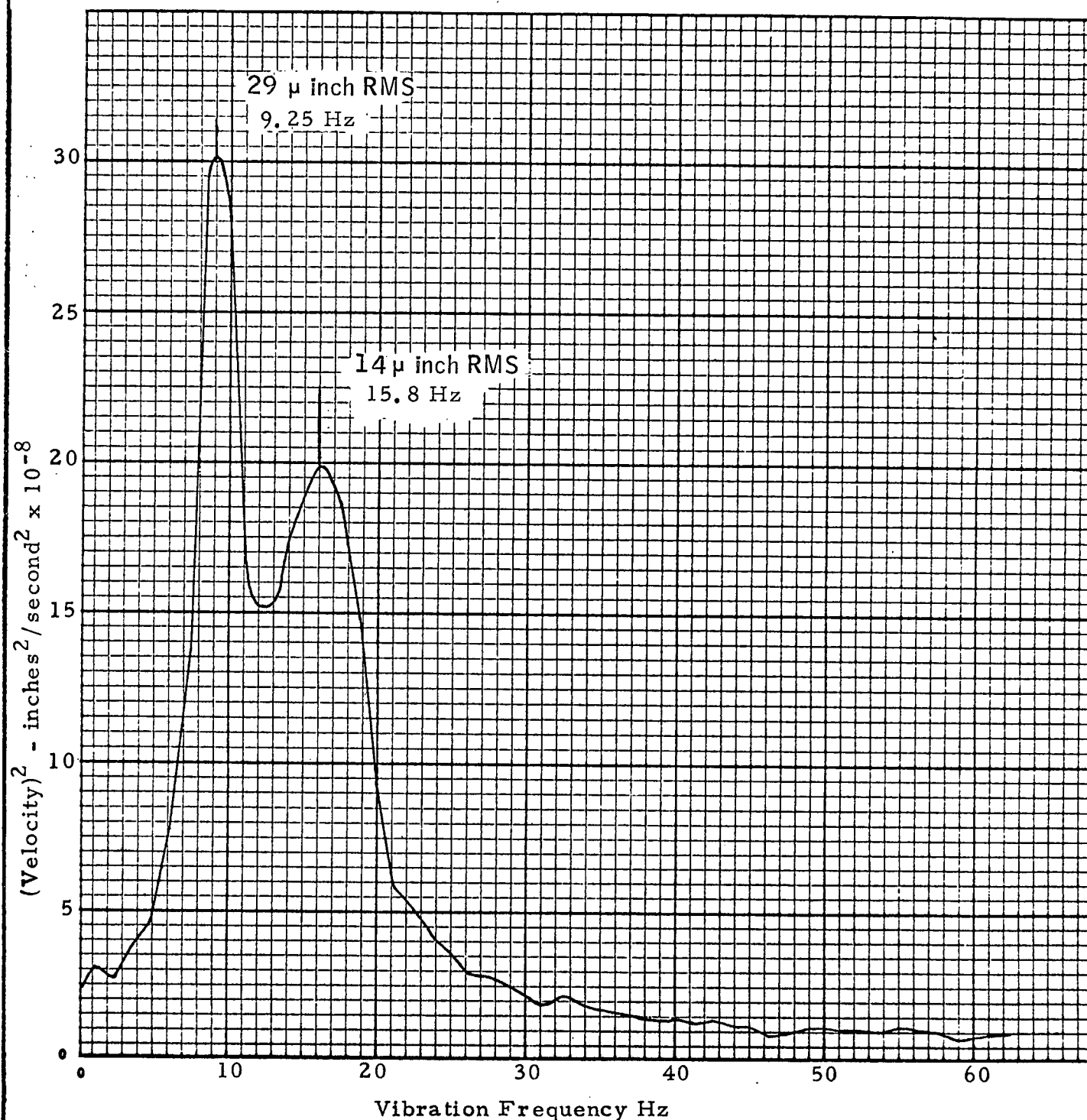


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Figure 5.1.1 - Power Density Spectrum, Floor Ambient Vibration

Test 51-ab, T & EB Lab, 3 June 1971, 0830, Vertical
Vibration recorded in the center of the floor slab.

$$\sigma_v^2 = .566 \times 10^{-5} \text{ in}^2/\text{sec}^2, \sigma_D^2 = .253 \times 10^{-8} \text{ in}^2, \sigma_D = .505 \times 10^{-4} \text{ in.}$$



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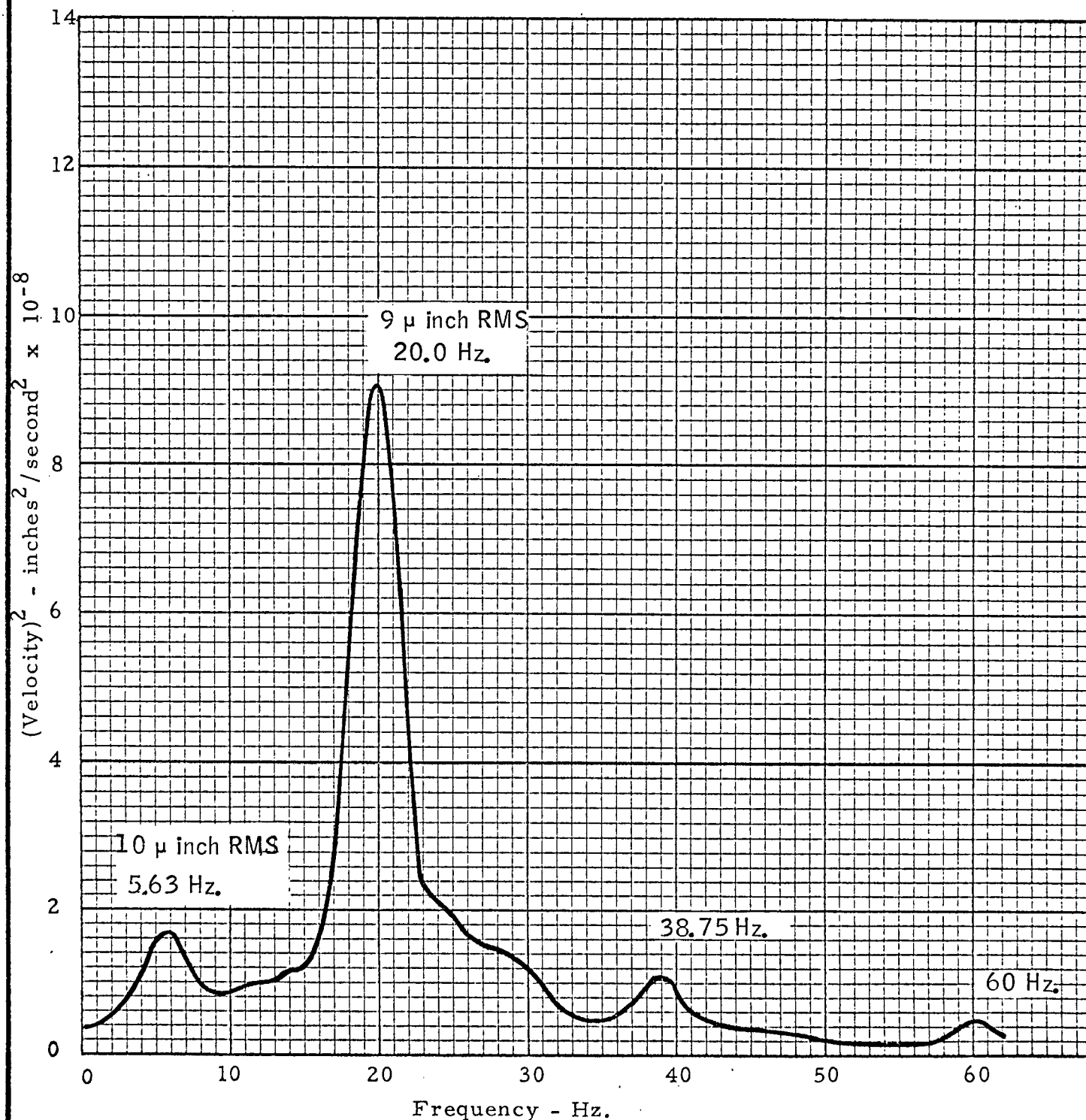
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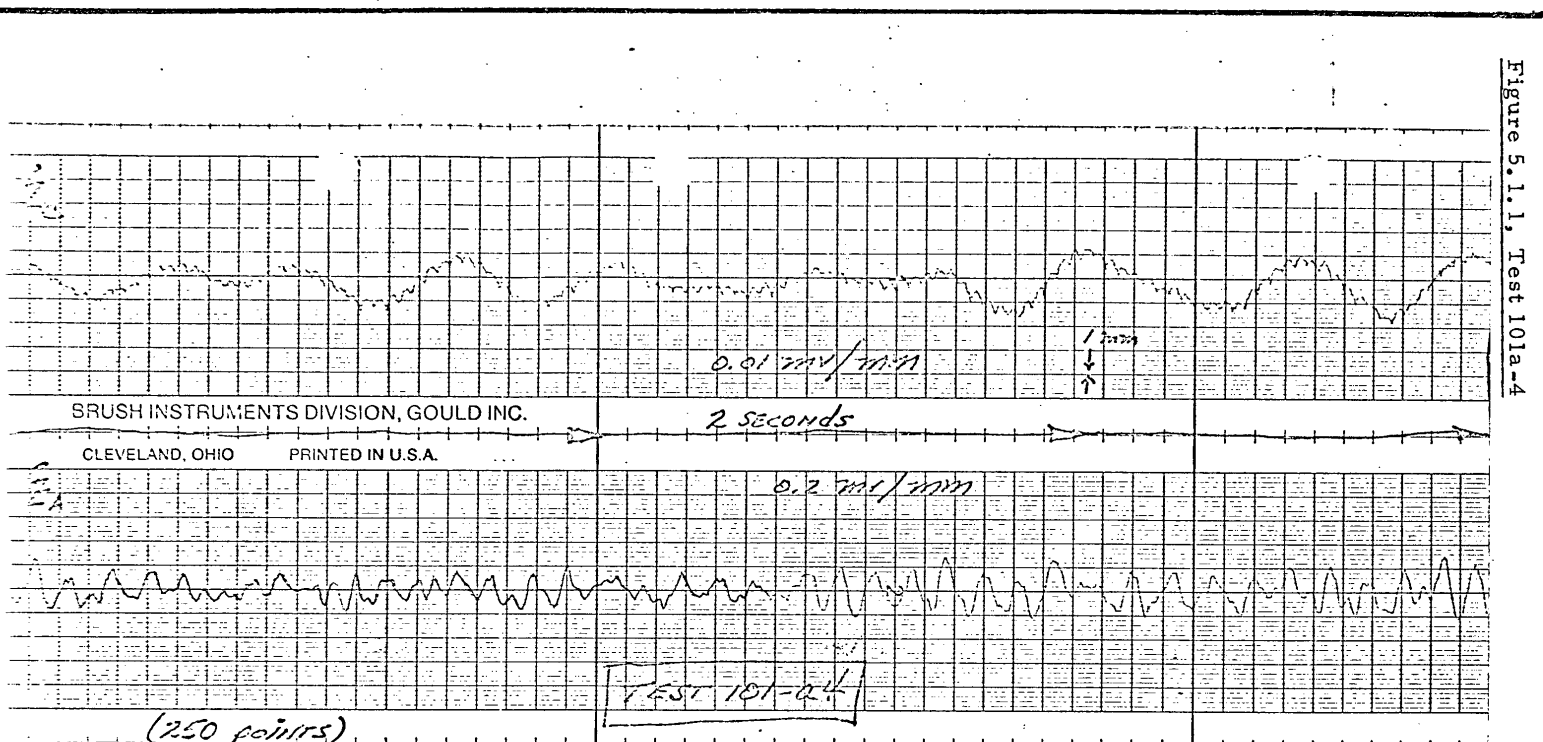
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Figure 5.1.1 Power Density Spectrum - Floor Ambient Vibration, Test 101-a4

Data is from vertical velocity recording (\dot{Z}_a) made at 1400
on 2 August 1971 in Clean Room of NRC Table, Advanced Technology Branch





Test 101a-4

Response of NRC table to floor ambient vibration, 2 August 1971, 1400 Hrs.

Z_c measured in middle of table (vertical vibration)

Geophone record, Z_c , 0.01 mV/mm = 22×10^{-6} inches/second per chart mm

Z_a measured on floor near center of slab and at edge of table (vertical vibration)

Geophone record, Z_a , 0.2 mV/mm = 44×10^{-5} inches/second per chart mm

Chart speed 125mm/second

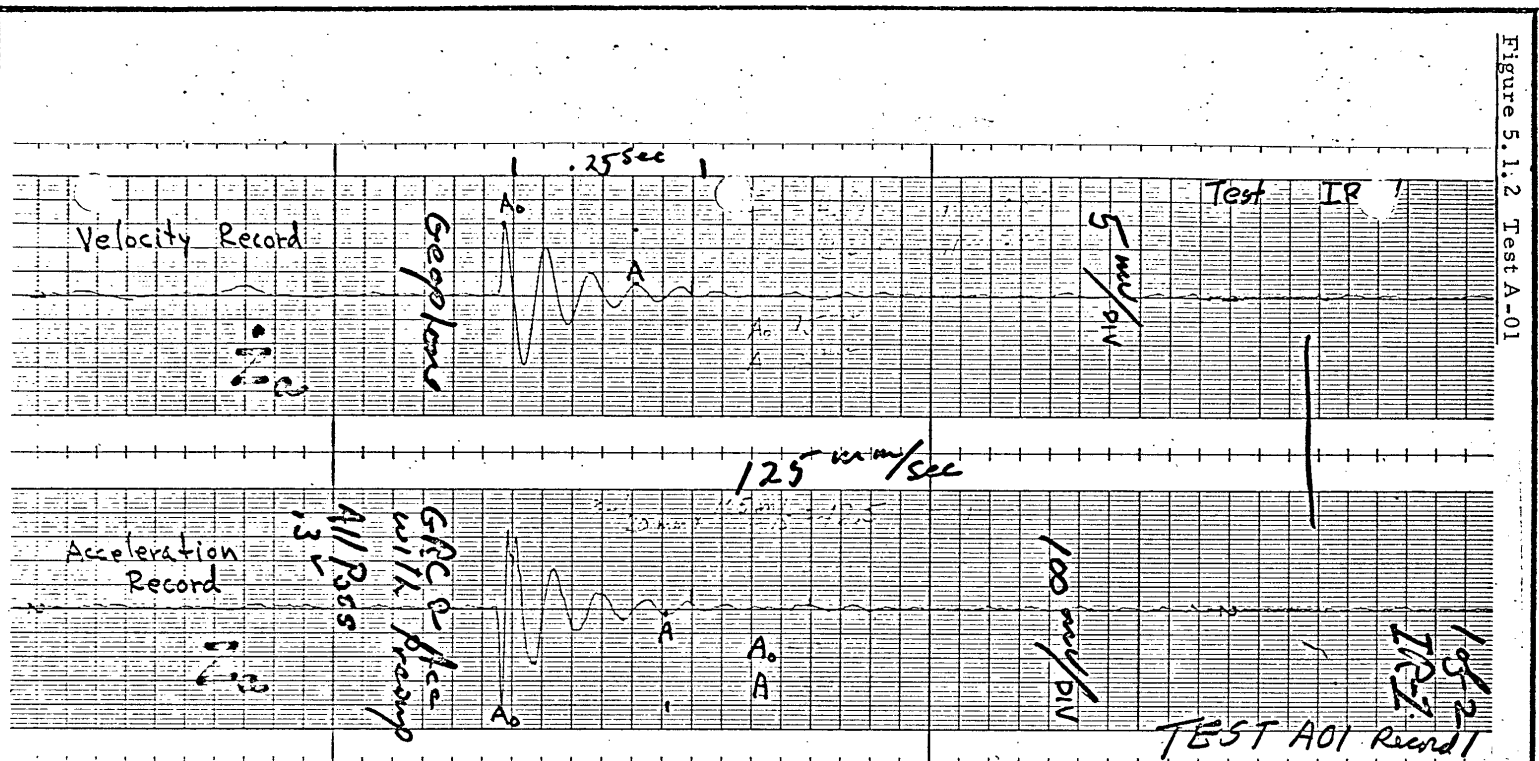
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Test A-01

Impulse Response of Typical Floor Slab - 18 May 1971, 1400 Hrs.
 Response from a single impulse at the center of T & EB Laboratory Floor slab produced by jumping (JMP).
 Record of geophone and accelerometer signals "all wave"
 Geophone record Z_a , scale 1.0 mV/mm = 22×10^{-4} in./sec per chart mm
 Accelerometer record Z_a , scale 20 mV/mm, chart speed 125mm/sec

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Figure 5.1.2 Calculations, Floor Response

A-01 Impulse Response - 18 May 1971, 1400 Hrs.

Per Acceleration record,

$$A_o = 400 \text{ mV}$$

$$A = 20 \text{ mV}$$

$$t_i - t_o = 27.5 \text{ mm}$$

$$Z_a \quad t = 27.5 \text{ mm} \times \frac{1 \text{ sec}}{125 \text{ mm}} = .22 \text{ sec.}$$

$$f_o = \frac{4 \text{ cycles}}{.22 \text{ sec}} = 18.2 \text{ Hz}$$

$$\therefore \zeta = \frac{1}{2\pi f_o t} \left(\ln \frac{A_o}{A} \right) = \frac{1}{(6.28)(18.2)(.22)} (\ln 20) = \frac{3}{(6.28)(18.2)(.22)}$$

$$\zeta = .119 = 12\% \text{ of critical damping}$$

Per Velocity record,

$$A_o = 15 \text{ mV}$$

$$A = 2 \text{ mV}$$

$$\frac{A_o}{A} = 7.5$$

Z_a

$$t_i - t_o = 21.5 \text{ mm}$$

$$t = 2.15 \times \frac{1}{125} = .172 \text{ sec}$$

$$f_o = \frac{3 \text{ cycles}}{.172} = 17.45$$

$$\therefore \zeta = \frac{1}{(6.28)(17.45)(.172)} (\ln 7.5) = \frac{2.015}{(6.28)(17.45)(.172)} = 10.7\%$$

= say 11%

Average ζ determined by the two kinds of record.

$$\zeta = \frac{11.9 + 10.7}{2} = \underline{\underline{11.3\% \text{ of critical damping}}}$$

All measurements made in center of floor slab of T. & EB Laboratory.

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5.1 Tests of Ambient Vibration at Site Made During Program (Contd.)

Appendix Figure 5.1.1 Test 51-ab
Appendix Figure 5.1.1 Test 101-a4

These spectra were used in deriving the curves of Report Figure 5.3.1.

An impulse test of the floor in the T & EB Laboratory was also made on 18 May 1971. Appendix Figure 5.1.2 shows the impulse recording and calculation of damping resulting from the test.

5.2 Impulse Test of Tilt-up Building Floors

The response of floor structures to impulse was recorded to determine dominant frequencies and associated damping. A single impact (heel kick) was used to excite the floor vibration which was recorded by adjacent geophone. The tests and measurements were made approximately in the middle of a floor panel so the fundamental resonance would appear. Three individual impulse records were digitized and averaged. A harmonic analysis was calculated by computer to determine frequency and damping of the dominant responses.

Figure 5.2.1, Test DT-1 - Record of impulse on second floor. Steel beam, plywood diaphragm, tilt-up concrete building. 18 August 1971, DynaMetric, Inc. building, 330 West Holly, Pasadena, California

Figure 5.2.1, Test DT-2 - Record of impulse on ground floor slab, nominal 4-inch slab, wire mesh reinforced on compacted fill (decomposed granite) 18 August 1971, DynaMetric, Inc. building, 330 West Holly, Pasadena, California

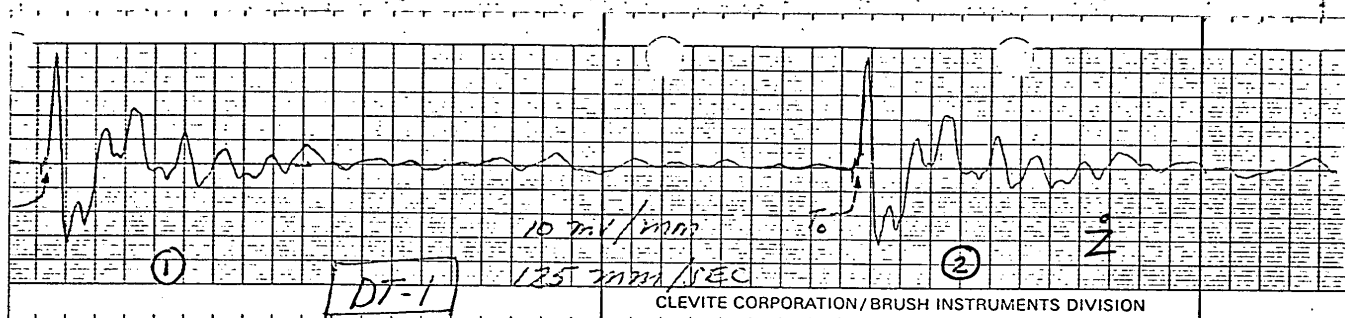
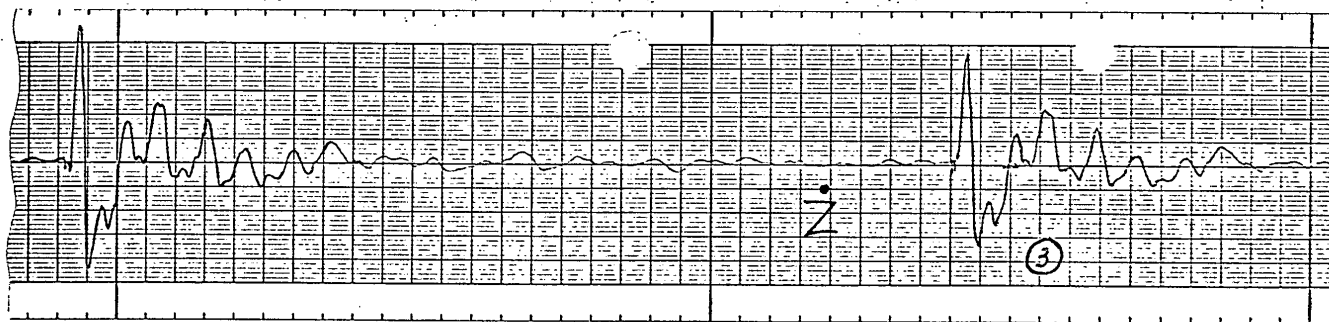


Figure 5.2.1, Test DT-1



Test DT-1

Impulse Test on second floor of DMI building, 18 August 1971
Structure is steel beam supported plywood diaphragm floor on "tilt-up" walls
Geophone record, \dot{Z} , made for three impacts
Scale 10 mV/mm = 22×10^{-3} inches/second per chart mm
Chart speed equals 125mm/second

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Figure 5.2.1, Test DT-2

Impulse Test on ground floor slab of DMI Building, 18 August 1971
 Nominal four-inch slab, wire mesh reinforced on compacted decomposed granite fill.

Geophone record, \ddot{Z} , made for three impacts

Scale $.2 \text{ mV/mm} = 44 \times 10^{-5} \text{ inches/second per chart mm}$

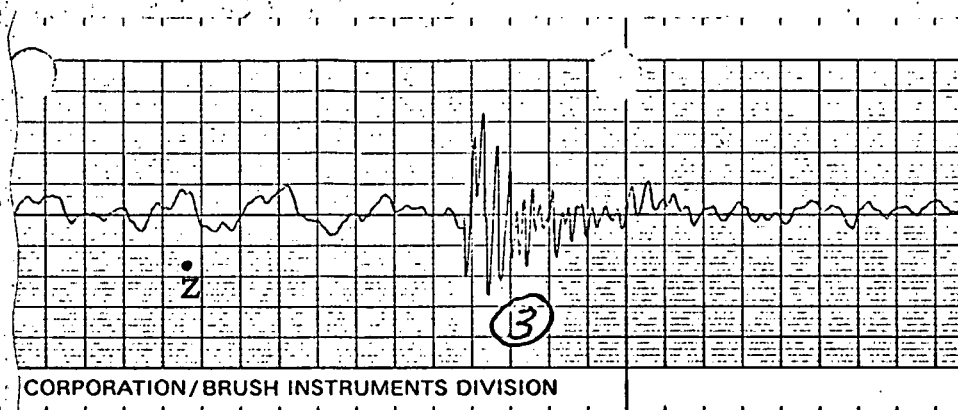
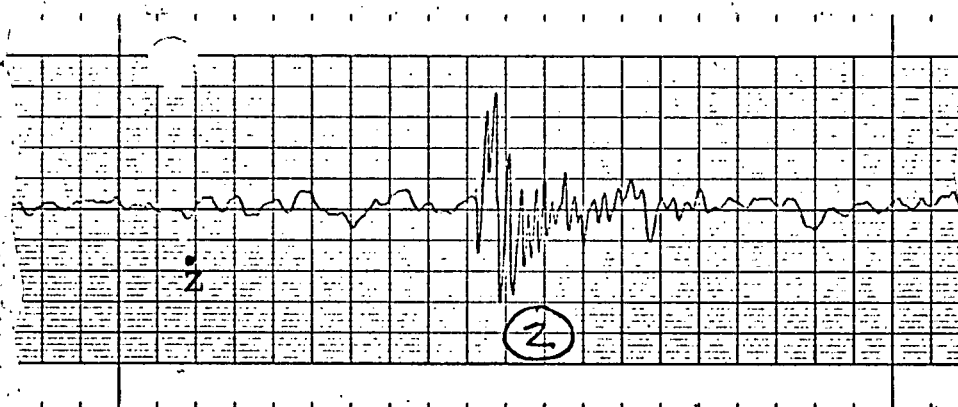
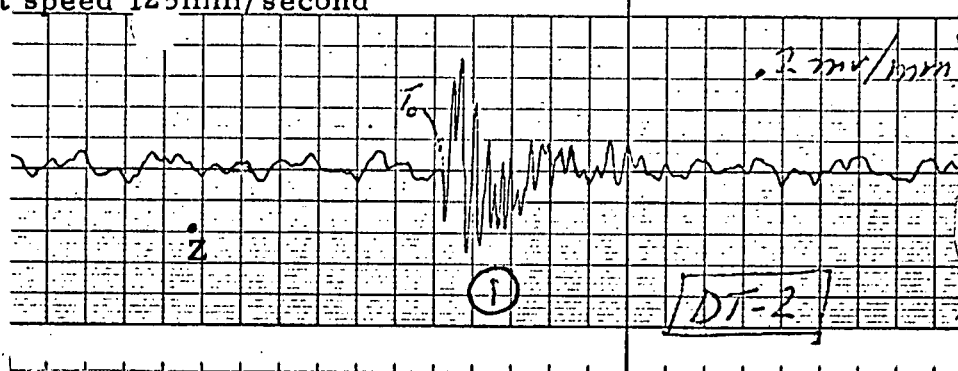
Chart speed 125mm/second

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5.3 Impulse Test of Masonry Structure

Tests were run on stresscore plank floors in a building with hollow, solid-grouted reinforced concrete masonry unit-bearing walls (Pasadena Hilton Hotel)

5.3.1 Purpose of Tests and Description of Building Tested

One type of building system proposed as a possibly "quiet" structure from the standpoint of ambient building vibration transmission, low response to external and internal excitation, and relatively high structural damping, is that utilizing the pre-stressed concrete plank floor system, with concrete topping. The concrete planks normally span from 22 to 30 feet, and are supported either on the beams of a structural frame, steel or concrete, or on concrete masonry unit bearing walls. For the purpose of providing the "quietest" building, the bearing wall support method would appear best.

A recently completed large building of the type described above is the Pasadena Hilton Hotel. The hotel tower, a 10-story complex completed in 1970, is entirely of concrete masonry unit bearing wall construction. All floors above the mezzanine level are "Stresscore" pre-stressed concrete planks, spanning 25'-2" center-to-center of supporting walls. For the room accommodations, the 25-foot span is further divided by non-structural "dry-wall" partitions, into equal 12-1/2 foot rooms. The 6-inch thick "Stresscore" planks are laid side-by-side across the walls. A 2-1/2 inch-thick topping of hard-rock concrete is then placed. This topping runs into shear-key grooves between the planks, locking them together for distribution of floor loads. However, this joint would permit the very small motions needed for structural damping. At the bearing walls, the floor system is tied to the walls by reinforcing bars that lap with the wall steel and bend into the slab topping. Diaphragm action of the floor for the distribution of the wind and seismic lateral loads horizontally between building shear walls is provided by flat steel bars, laid in the topping directly on top of the concrete planks.

In guest areas the concrete plank floors are finished on the underside by pneumatically applied acoustical plaster for ceilings. In services areas, the planks are simply painted. Floor finished areas are rich, thick looped-pile carpet over thick foam padding in the halls, long-shag carpet with no padding in guest rooms, and ceramic tile in baths. Service area floors are plain concrete.

The purpose of the tests made 24 August 1971, on the Pasadena Hilton Hotel tower structure was to determine the typical floor resonances and damping ratios that can be expected from this type of construction. Ambient vibration levels in the building, on the 4th and 10th floors were recorded. Finally, a test designed to evaluate the carpeted and non-carpeted floor finishes from the standpoint of "deadening" of impacts from human traffic was conducted.

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5.3.2 Vibration Sources, Pasadena Hilton Hotel

The tests were conducted between 10:30 AM and 1:00 PM, while street traffic was at its normal, mid-day level. The building is adjacent to light street traffic on the south side, medium traffic on the west side (Los Robles Avenue) and fairly heavy commercial traffic on the north side (Green Street). The east side of the tower structure contains a five-level parking structure. Between the parking structure and the hotel tower, is a two-story building housing marquee shops, restaurants, convention rooms, and the facility's main air-conditioning plant and kitchens. Immediately north of the hotel tower, but not connected to it, is a new Hilton office tower, just being completed (Fall 1971). No heavy construction is in progress, and the lower five floors are occupied. The office tower is not of concrete pre-stressed plank and bearing wall design. It is a monolithically placed, reinforced-concrete structural frame and paneled reinforced concrete floor structure. The difference in construction was due to the fact that varying occupancy load in the office tower required flexibility in the location of partitions, while the hotel could be designed for fixed rooms.

During the tests described below, the hotel was in normal week-day operation, with a medium occupant load. Service personnel were at work on the various floors. The elevators and laundry chutes, kitchens, air-conditioning system and other facilities were operating in the usual manner.

5.3.3 Instrumentation Used for the Tests, Pasadena Hilton Hotel

The vibrations of the floor system were transduced by a vertical EVS-8 geophone having an effective damping resistance of 545 ohms (1000-ohm shunt plus a parallel 1200-ohm input impedance of the amplifier) thus operating at 58% of critical damping. The geophone signal was amplified by the DMI low-frequency linear amplifier, and recorded on one channel of a Brush Mark 220 Recorder at a chart speed of 125-mm per second. For ambient noise recording, record sensitivity was .05 mV per chart mm. For impulse testing, the record sensitivity was reduced, to one-tenth of the above, or 0.5 mV per chart mm. For the traffic impact on carpeted and uncarpeted floor tests, record sensitivity was 0.2 mV per chart mm.

The locations of the tests, with geophone locations, \dot{Z}_a , b , ..., are shown on instrumentation sketch sheet A102.

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5.3.4 Detailed Description of Tests, Pasadena Hilton Hotel

Test Series 102a, through 102d

- Purpose: Monitor and record ambient vibration levels in the floor system. Record the response of the floor to heel impacts, in order to determine resonant frequencies of response and damping ratios.
- Method: Using vertical geophone with amplifier and Brush recorder, record steady-state ambient vibrations for a suitable time interval. After recording ambient vibrations, adjust sensitivity of the recording system as required to keep record on-scale, and make a series of impacts on the floor with the weight of the body applied through the heels. Record the floor responses. Be sure that the effects of one impact have entirely died out before making another.
- Test 102a-1 Made on the north stair landing, of the 4th floor. The vertical velocity components of ambient vibrations were recorded in the center of the landing slab. Several heel impulses were applied to the slab, and the responses recorded.
- Test 102b-1 Made in the service hall, or vestibule, off the elevator lobby in the 10th floor. Ambient vertical velocity components were recorded at the center of the floor, Z_a .
- Test 102b-2 Same, \dot{Z}_a , responses from several heel impulses on the floor.
- Test 102b-3 Same as 102b-1, but with the geophone at \dot{Z}_b (see sketch A102).
- Test 102b-4 Same as 102b-3, responses from several heel impulses made near "a", and recorded at "b", Z_b .
- Test 102b-5 Same as 102b-4, responses from several heel impulses made near "b", and recorded at "b", Z_b .

Returned to the 4th floor:

- | | | |
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| <u>Test 102c-1</u> |) | |
| <u>Test 102c-2</u> |) | These tests were all identical with the tests numbered |
| <u>Test 102c-3</u> |) | 102b-, except that they were made in the same plan |
| <u>Test 102c-4</u> |) | locations, in the service hall on the 4th floor. |
| <u>Test 102c-5</u> |) | |

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(Continued: Detailed Description of Tests, Pasadena Hilton Hotel)

Test 102d-1 The 102d- tests were made in the approximate center of the 4th floor, in guest room 425. The entire area of the hotel guest floors is carpeted, with the exception of the service halls and the ceramic tile floors of the baths. The geophone was placed on the tile floor of the room 425 bath. This is in the center of a 25' "Stresscore" plank span, adjacent to a non-structural partition.

The first test was to record the vertical velocity component of ambient vibrations, \dot{Z}_d . (See sketch Figure 5.3.4.1)

Test 102d-2 Several heel impulses were made on the tile floor of the bath, and the responses recorded, \dot{Z}_d .

Test 102d-3 Several heel impulses were made on the carpeted floor of the guest room, just outside the door to the bath, and their responses were recorded, \dot{Z}_d .

Test Series 102e-

Purpose: During the impulse on carpet test, 102d-3, it was observed that the effect was much less than that of impulses on the hard floor. Therefore it was decided that the test set-up afforded an excellent opportunity to compare the effect of unpadded shag carpet, and thickly padded looped-pile carpet (in the nearby hall) as a vibration-lessening medium (impact softener).

Method: While recording the vertical velocity component of vibrations at a point on the ceramic tile floor, Z_e —equally distant from suitable test areas on tile, shag, and looped-pile carpets—the effect of heavy walking was simulated, and the responses recorded at "e", as shown on sketch A102.

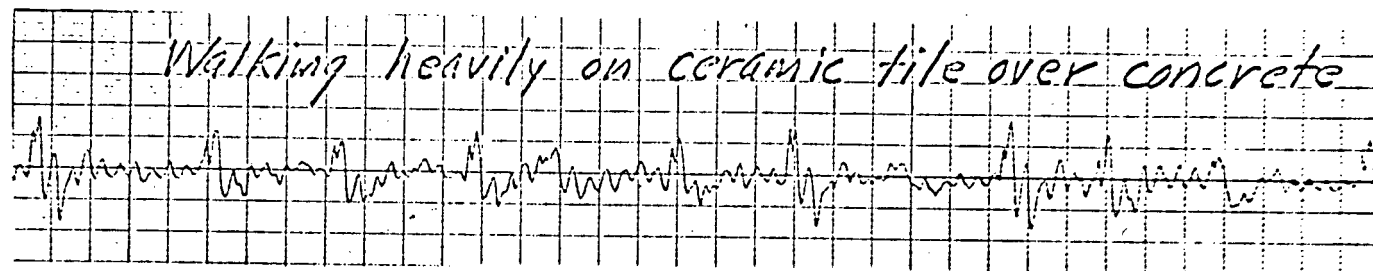
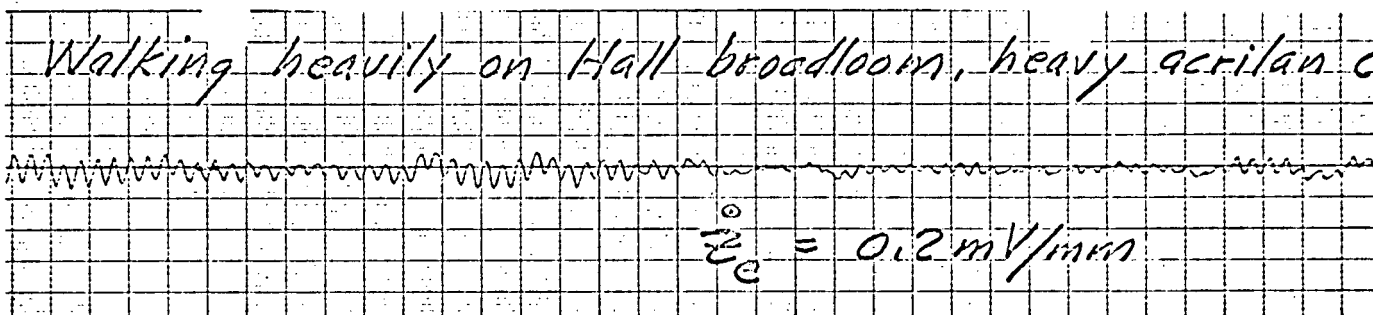
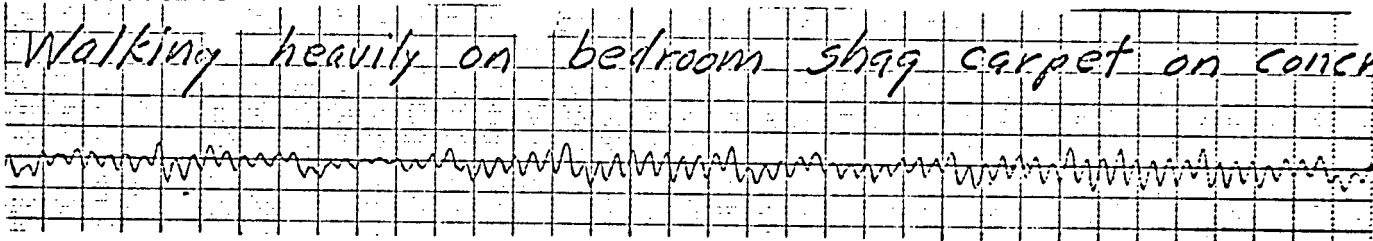
Test 102e-1 Walking heavily on the ceramic tile floor.

Test 102e-2 Walking heavily on heavy looped-pile carpet over thick padding.

Test 102e-3 Walking heavily on shag carpet, no pad, over concrete floor.

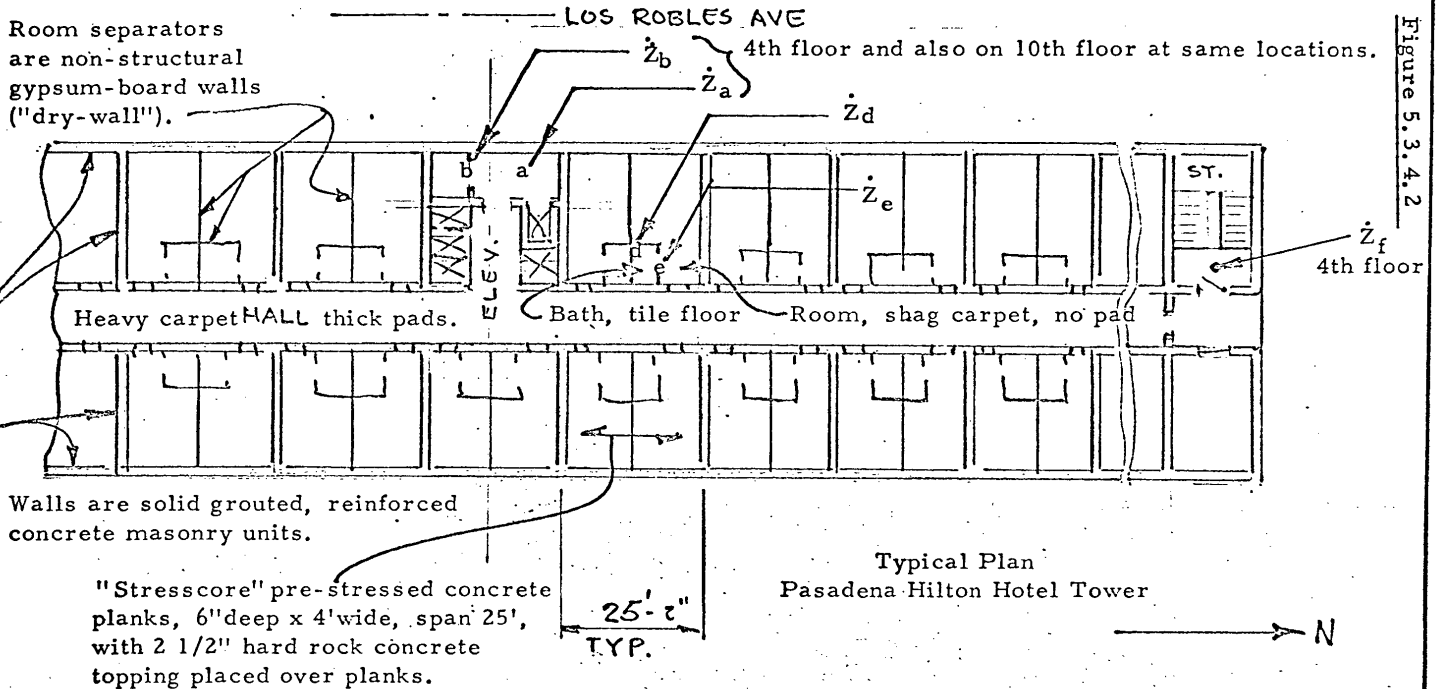
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Figure 5.3.4.1 Test 102e-1, 102e-2, 102e-3

Test 102e-1 Effect of walking on hard-surfaced floor.Test 102e-2 Effect of same walking on richly carpeted, padded floor.Test 102e-3 Effect of same walking on shag-carpeted, unpadded floor.

Transducer location and record sensitivity and chart speed were the same for all three tests. Areas walked upon were equidistant from the transducer. Every effort was made to reproduce the same type and intensity of walking disturbance.

Record sensitivity = 0.2 mV per chart mm.
Geophone conversion = 1mV = 2.4×10^{-3} inches per second.
Record chart speed = 125 mm per second.



Tests performed on the 10th floor and on the 4th floor, 24 Aug 71
(All tests on 4th floor only, unless noted on this plan.)

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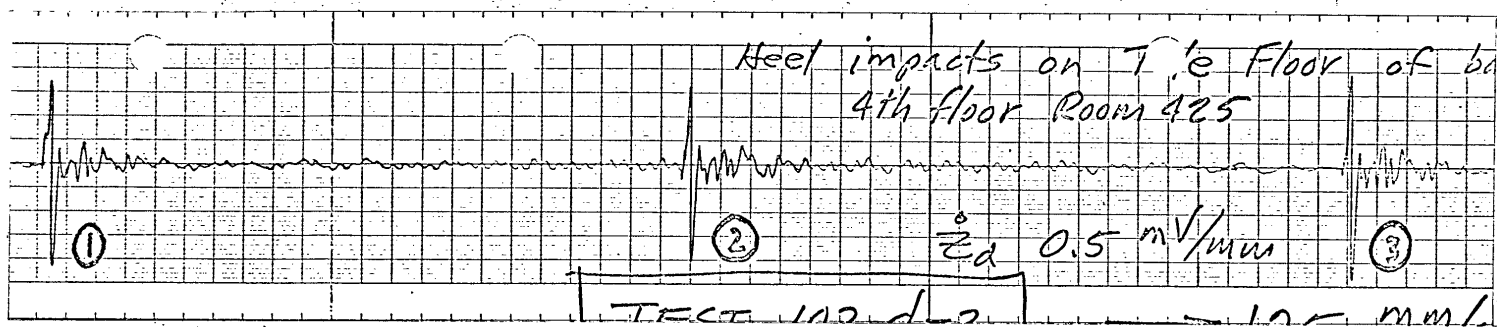
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Figure 5.3.4.3, Test 102d-2



Test 102d-2

Impulse Test of floor slab, fourth floor, approximate center of stresscore plank slab. Three impacts measured

Geophone record, \dot{Z}_d , scale 0.5 mV/mm = 11×10^{-4} inches/second per chart mm

Chart speed 125mm/second